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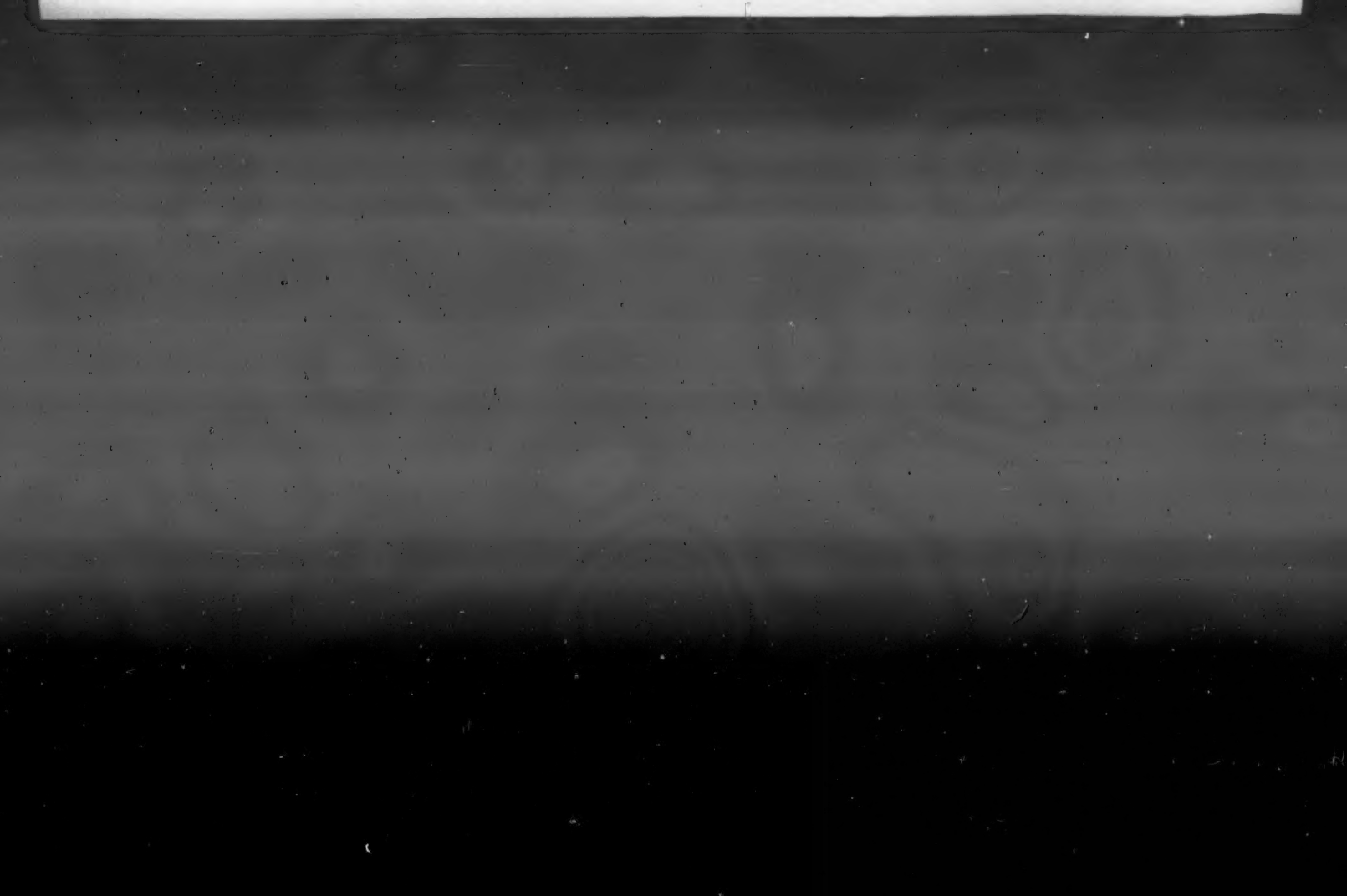

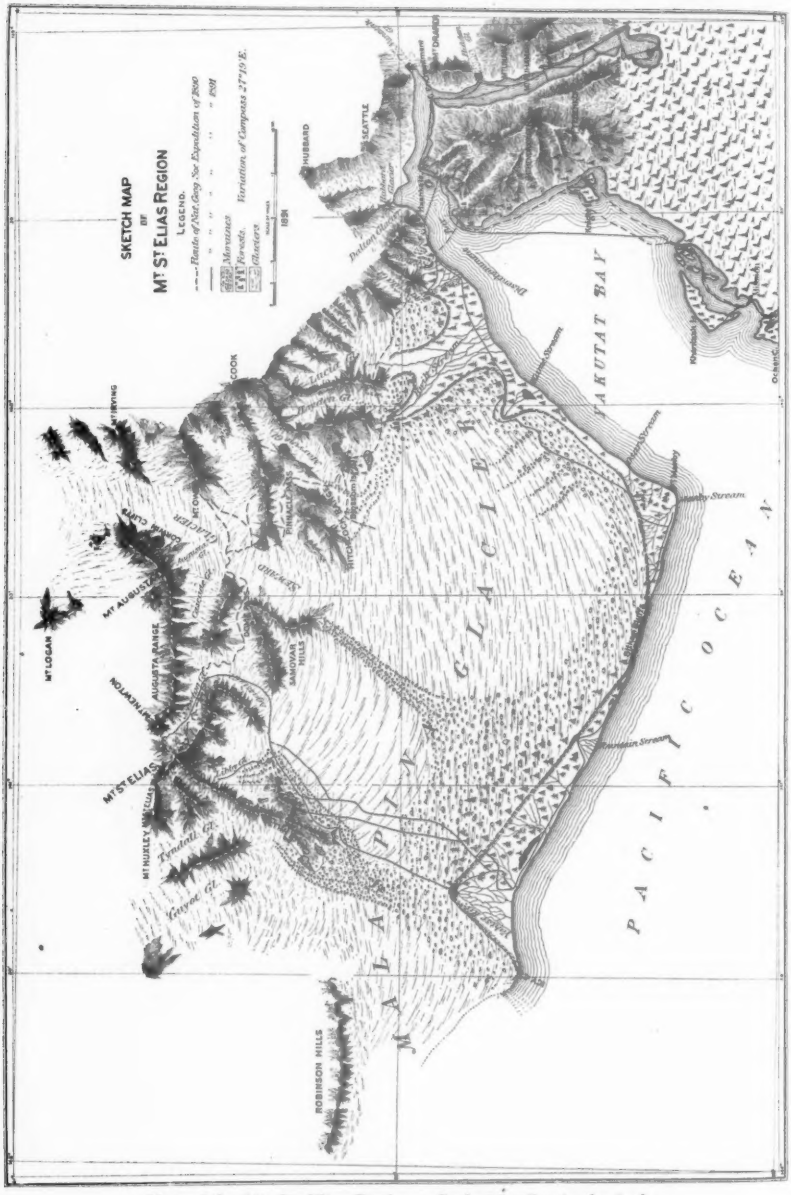

Map of the Mt. St. Elias Region. Scale 16 miles to the inch.

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[THIRD SERIES.]

ART. XX.—*Mt. St. Elias and its Glaciers*;* by ISRAEL C. RUSSELL. With a map, Plate IV.

THE National Geographic Society, in connection with the U. S. Geological Survey, has sent two exploring parties to Mt. St. Elias, Alaska. The first in the summer season of 1890, and the second a year later. The object of these expeditions was to explore the region about Mt. St. Elias, and learn as much as possible of its geography and geology, and if practicable to climb the mountain itself, which is thought to be the highest summit on the North American continent.

I had charge of each expedition, and it is my object to give here a brief account of the country explored.

The southern shore of Alaska is probably as wild and inhospitable as any coast in the world. Lofty mountains, snow-clad throughout the year, rise almost directly from the ocean, and send down not only scores but hundreds of glaciers to sea-level. From Cross sound to Kayak island, a distance of 300 miles, there is only one break in the iron-bound coast, in which ships can take refuge, that is Yakutat bay, fifty miles east of Mt. St. Elias. On the east side of Yakutat bay near its entrance, there is an Indian village, a mission and a trading-station. This is the nearest human habitation to Mt. St. Elias, and was the basis from which we began our explorations.

* Abstract of a lecture before the Geological Society of America, at Columbus, Ohio, Dec. 29, 1891.

Expedition of 1890.*

In 1890, I left the Mission at Yakutat, early in June, with eight companions, and proceeded by boat to near the head of Yakutat bay, where our tramp toward the interior began. We worked our way slowly northwestward towards Mt. St. Elias for fifty miles across mountain spurs and over glaciers. More than nine-tenths of the journey was over rough ice or on the névés from which the glaciers flow. We reached an elevation of 7500 feet on the north side of Mt. St. Elias, but were caught in the early winter storms and forced to retreat.

During this journey we became acquainted especially with the great névé fields on the mountains, and explored a large part of the northern border of the great Piedmont glacier, which is of the nature of a vast lake of ice, formed by the union and expansion of several large Alpine ice streams on the plain intervening between the mountains and the sea. This veritable *Mer de glace* is known as the Malaspina glacier. It was thus named by the Superintendent of the U. S. Coast Survey several years since, in honor of Don Alejandro Malaspina, an Italian explorer in the service of Spain, who visited the southern coast of Alaska in 1792 The Malaspina is the most interesting of all the glaciers in the St. Elias region, and will be briefly described a few pages in advance.

Expedition of 1891.

Early in June of the present year, I returned to the St. Elias region, and after calling at the Mission at Yakutat, landed at what is known as Icy bay, fifty miles west of Yakutat bay, and there began again the study of the geography and geology of the region to which I wish to direct attention.

With five camp hands for companions, I crossed the Malaspina glacier to the Chaix hills, and from there went up the Agassiz and Newton glaciers. Our highest camp was in the snow in the great amphitheater in which the Newton glacier rises, between Mt. Newton and Mt. St. Elias, and at an elevation of 8000 feet. We occupied it for twelve days, and during that time owing to clouds and snow storms, were able to make but one advance. On the day we did advance, we climbed to the divide between Mt. Newton and Mt. St. Elias and from there ascended the north slope of the great pyramid forming the summit of Mt. St. Elias, until we reached an elevation a little over 14,500 feet above the sea.

From the divide and while climbing the slope above it, we had an unobstructed view of the vast unexplored region

* A popular account of this expedition appeared in the National Geographic Magazine for May 1891.

north of the St. Elias range. The day was unusually beautiful and a strange land, which had never before been seen by man, lay spread out like a map beneath our feet. Having previously crossed the mountain system of which the St. Elias range forms a part, some 200 miles east of Mt. St Elias, and traversed the country to the northward, I expected on reaching the divide between Mt. Newton and Mt. St. Elias, to behold a similar region. I pictured to myself a comparatively low forested land, interspersed with lakes, and divided by streams, and perhaps giving some signs of human occupation. But I was entirely mistaken. What did meet my astonished gaze was a vast snow-covered region, limitless in its expanse, through which hundreds and probably thousands of barren, angular mountain peaks project. There was not a stream, not a lake, and not a vestige of vegetation in sight. A more desolate or a more utterly lifeless land one never beheld. Vast, smooth, snow surfaces, without crevasses or breaks, stretched away to seemingly limitless distances, diversified only by jagged and angular mountain peaks. The general elevation of the snow surface is about 8,000 feet, while the mountain peaks which pierce it are from ten to twelve thousand feet or more, in altitude above the sea. To the north I could see every detail in the forbidding landscape for miles and miles. The most distant peaks in that direction were forty or fifty miles away. To the southeast was Mt. Fairweather, sharply defined against the sky, although 200 miles distant. About an equal distance to the northwest are two prominent mountain ranges, the highest peaks of which appeared to be as lofty as Mt. Fairweather. These are in the vicinity of Mt. Wrangell, but no volcanic vapor could be seen about them. Whether any one of them was Mt. Wrangell or not I was not able to decide.

The view to the north called to mind the pictures that explorers give of the borders of the great Greenland ice sheet, where many rocky islands, known as *nunataks*, alone break the monotony of the boundless sea of ice. The region before me was a land of nunataks.

If those of my readers who are familiar with the Great Basin of the Far West, will fancy the most desolate portion of that arid region buried beneath a thousand feet of snow and ice, leaving only the southern slopes of the most rugged peaks exposed, they will have a mental picture of the land of desolation north of Mt. St. Elias.

Owing to long continued stormy weather, we were forced to abandon the hope of reaching the summit of Mt. St. Elias and returned to Icy bay.

On reaching the flat lands along the ocean, near the mouth of the Yahtse, we measured a base line three miles long and

obtained the necessary measurements of angles for determining the height of Mt. St. Elias and of a few of its neighbors. Computations based on these measurements, show that Mt. St. Elias has an elevation of 18,100 feet, plus or minus a probable error of less than 100 feet.

From Icy bay we tramped eastward along the coast to the head of Yakutat bay, and thus became familiar with the outer border of the Malaspina glacier. After reaching the head of Yakutat bay we explored the continuation of the same inlet, known as Disenchantment bay. The entrance to the inner bay was discovered by Malaspina in 1791, while searching for a passage between the Pacific and the Atlantic. At first the opening in the mountains at the head of Yakutat bay, gave hope that the long-looked for "Northwest Passage" had been found, but on entering it Malaspina learned his mistake and as an indication of his disappointment, named the inlet "Puerto del Desengaño," which has been changed by English writers, to "Disenchantment bay."

When Disenchantment bay was discovered, the Hubbard and Dalton glaciers had a greater extension than at present and uniting at Haenke island, blocked the inlet from shore to shore with a wall of ice similar to that now formed by the Hubbard glacier.

Disenchantment bay was next visited by Capt. Puget of Vancouver's expedition, in 1794, and was found to be blocked by ice, as had been described by Malaspina.

This is the last report we have of the condition of the ice in the bay, until our visit in 1890. When the Revenue Steamer *Corwin* called for us at the close of the season, we steamed up the bay past Haenke island, to within half a mile of the ice cliffs of the Hubbard glacier, and then turned back without exploring its eastern extension. It is reported that two prospectors in their search for gold visited the eastern arm of the bay a few years since, but of this excursion there is no record.

In the fall of 1891, I again visited the bay and with two companions explored its entire extent. We found it to be prolonged nearly due east from the Hubbard glacier for about ten miles, with a width of about three miles. From near the east end of this arm, beginning at what I have called Cape Enchantment, there is another arm, looking like a broad, placid river, from two to three miles wide, which runs south for over twenty miles, and extending beyond the mountains, expands into a circular lake-like water-body in the flat lands between the mountains and the sea. A partial survey of this southern portion of the bay was made, but stormy weather coming on, all instrumental work had to be abandoned.

Disenchantment bay is surrounded on all sides by magnificent mountains. In grandeur of scenery, it is second to none of the wild fiords of southern Alaska. It resembles Lynn canal, which is familiar to many Alaskan tourists, but is narrower, more like a river, and the bold, snow-covered, and ice-scored mountains are nearer at hand. The precipitous shores bordering the east and west arm are bare of vegetation, and the southern arm is also desolate, except at the extreme southern end, where the bases of the mountains are forested. Its shores throughout, up to an elevation of over a thousand feet, bear evidences of recent glaciation. An interesting feature in which the southern arm differs from the other portions of the inlet, is furnished by conspicuous gravel terraces, which score its sides in even, horizontal lines up to a height of about 150 feet. These terraces sweep about the bluffs of gravel enclosing the lake-like expansion at the south, showing that the water-body which made them did not find an outlet in that direction. As the entrance of the bay was blocked with ice when visited by Malaspina and Puget. it seems reasonable to suppose that the water-body in the southern arm owed its existence to the ice dam thus formed. The terraces are therefore about 100 years old. The numerous small stream-channels which cross them, show what has been accomplished in the way of subaërial degradation in a century.

Geology.

Concerning the geology of the St. Elias region our knowledge is very imperfect. Owing to the great extent of glaciers and snow-fields, opportunities for studying the formations beneath are exceedingly rare.

All of the rocks about Yakutat and Disenchantment bays, with the exception of a few intrusions of diorite and certain thin beds of limestone, are brown sandstone and dark shales. The dip of these strata is almost invariably to the northeast. Their thickness is great, but has never been even approximately estimated, owing to the fact that they have apparently, been crushed and overthrust on a grand scale. These beds constitute a well-defined formation, which has been named the Yakutat system. North and west of the area occupied by the Yakutat system, and for several reasons thought to be older, there is a series of shales, limestones and conglomerates, that have been named the Pinnacle system, on account of their appearance in a long line of cliffs at Pinnacle pass. In the cliffs at Pinnacle pass there is a bed of bowlders, which was observed in 1890, but its true character was not fully recognized until the following year. It was then found that what

is probably an extension of the same bed, increases very greatly in thickness toward the west and forms the Samovar, Chaix, and probably the Robinson hills. These hills are formed of sandy shale, filled with both angular and rounded stones and bowlders which represent a great variety of rocks. This terrane is a morainal deposit, and was formed in the ocean from the debris of glaciers which broke off in bergs. In the Chaix hills this deposit is over 4000 feet thick and is composed of conformable brown and gray strata, dipping northward at an angle of about ten degrees.

The topographic form of Chaix hills shows that they have been formed by a monoclinal uplift, of very recent date. Although composed of soft beds, they have not been deeply dissected by erosion. This conclusion as to the recency of the uplift to which they owe their prominence, is fully sustained by the fossils with which some of the beds are charged. All of the shells obtained are of species still living in the adjacent ocean.

North of the principal outcrops of the Pinnacle system are sandstones and shales that are lithologically undistinguishable from the characteristic rocks of the Yakutat system. These dip under the crystalline rocks forming the Augusta and St. Elias ranges, and form the actual bases of the mountains. From such facts as have been observed, I have ventured the hypothesis that the schists have been overthrust on to the sandstones and shales, and hence that the uplifting of the mountains is an event of very recent date. This conclusion was reached during the expedition of 1890, and was tested the following year, but without succeeding in fully demonstrating it, or finding evidence which would militate strongly against it. It must stand, therefore, as an interesting hypothesis, which awaits additional study.

The cliffs in which the rocks of the Pinnacle system are exposed at Pinnacle pass and in the Samovar, Chaix and Robinson hills, are monoclinal uplifts, due to the elevation of one side—in these cases always the north side—of faults. The Augusta and St. Elias ranges are also monoclinal uplifts. Nothing of the nature of anticlinal or synclinal folds was observed in the region explored. The prevailing and characteristic structure is monoclinal and very similar to the Great Basin type. The ranges including those immediately north of Mt. St. Elias have steep escarpments on one side and a gentle slope corresponding approximately with the dip of the strata, in the opposite direction. The ranges are short and in general trend northeast and southwest. Their steepest slopes are toward the southeast.

After the uplift of the mountains, glaciers seem to have taken immediate possession and to have protected the rocks from ordinary stream erosion. It is an interesting fact demonstrated to my own satisfaction at least, that the present ice drainage is consequent on the orographic structure. The glaciers in many instances follow the courses of faults, and ice falls occur in so many instances when the glaciers cross fault scarps, that their presence may be predicted from such a distance that only the general orographic structure is distinguishable.

Glaciers.

Although the St. Elias region is full of novelty and interest to the geographer and geologist, its chief attractions are for the glacialist.

The lower limit of perennial snow or the "snow line," is at an elevation of about 2000 feet above the sea. Above that elevation all of the mountains excepting the most precipitous cliffs are loaded with snow throughout the year. This snow forms the reservoirs from which flow hundreds of glaciers of the Alpine type. Some of these, as the Seward glacier for example, are fully fifty miles long and over three miles broad at the narrowest point. They are veritable rivers of ice which slowly drain away the snow that accumulates on the mountains. Besides the great ice-rivers there are very many secondary and tertiary glaciers, which do not form well defined streams. Some of these are of the same type as the small ice bodies that still linger in the cirques of the High Sierra of California, and illustrate the fact that the term "glacier" has a wide range so far as the size of the ice bodies to which it is applied, is concerned.

The glaciers of the Alpine type which flow southward from the mountains, for fully a hundred miles west of Yakutat bay, unite on the plain between the base of the mountains and the sea, and form one immense *Piedmont glacier*. This has been named the

Malaspina Glacier.

Area.—This glacier extends with unbroken continuity from Yakutat bay seventy miles westward, and has an average breadth of between twenty and twenty-five miles; its area is approximately 1500 square miles, or intermediate in extent, between the State of Rhode Island and the State of Delaware.

The Malaspina glacier is a vast, nearly horizontal, plateau of ice, with a general elevation of about 1500 feet. The central portion is free from moraines and dirt but is rough and broken

by thousands and tens of thousands of small crevasses. Its surface is broadly undulating, and recalls the appearance of portions of the rolling prairie lands west of the Mississippi. It is in fact a dreary and lifeless prairie of ice. From the higher swells of its surface one may see for miles in all directions without observing a single object to break the even monotony of the broken ice plain.

On looking down on the glacier from an elevation of two or three thousand feet on the hills bordering it on the north, even on the wonderfully clear days that follow storms, its limits are beyond the reach of vision.

Moraines.—From any commanding station overlooking the Malaspina glacier, as from the summit of the Chaix hills for example, one sees that the great central area of clear, white ice, is bordered on the south by a broad, dark band formed of bowlders and stones. Outside of this and forming a belt concentric with it, is a forest covered area, in many places four or five miles wide.

In a general view, by far the greater part of the surface of the glacier is seen to be formed of clear ice; but in crossing it, one comes first to the moraine and forest covered border, which owing to the great obstacles it presents to travel, impresses one as being far more extensive than it is in reality.

The moraines not only cover all of the outer border of the glacier, but stream off from the mountain spurs that project into its northern border. One of these trains starting from a spur of the Samovar hills crosses the entire breadth of the glacier and joins the marginal moraine on its southern border. This long train of stones and bowlders is really a highly compound medial moraine, formed at the junction of the expanded extremities of the Seward and Agassiz glaciers. These two great ice-rivers are entirely above the snow line, and the debris which they carry only appears at the surface after the ice descends to the Piedmont region where the annual waste is in excess of the annual supply. The stones and dirt previously contained in the glacier are then concentrated at the surface, owing to the melting of the ice that contains them. This is the history of all of the moraines of the Malaspina glacier. They are formed of the debris brought out of the mountains by the tributary Alpine glaciers, and concentrated at the surface by reason of the ablation of the ice.

Lobes.—The Malaspina glacier consists of three principal lobes, each of which is the expansion of a large tributary ice stream. The largest lobe has an eastward flow, toward Yakutat bay, and is supplied mainly by the Seward glacier. The next lobe to the west, is the expanded terminus of the Agassiz glacier; its current is toward the southwest. The third great

lobe lies between the Chaix and Robinson hills, and its main supply of ice is from the Tyndall and Guyot glaciers; its central current is southward. The direction of flow in the several lobes explains the distribution of the moraines about their borders.

The Seward lobe melts away before reaching Yakutat bay, but its southern margin has been eaten into by the ocean, forming the Sitkagi bluffs. The Agassiz lobe is complete, and is fringed all about its distal extremity by broad moraines. The Guyot lobe pushes boldly out into the ocean and breaking off, forms magnificent ice cliffs which are the finest of any of the tide-water glaciers of the Pacific coast. The waves undermining these cliffs, cause large masses of ice to break away and topple over into the sea, thus forming great numbers of bergs. This is the only instance known in Alaska, where a glacier advances into the open ocean.

Surface of fringing Moraine.—A peculiar and interesting feature of the moraines on the stagnant borders of the Malaspina glacier, is furnished by the lakelets which occur everywhere upon them. These are found in great numbers both in the forest-covered moraine and in the outer border of the barren moraine. They are usually rudely circular and have steep walls of dirty ice, which slope towards the water at high angles, but are undercut at the bottom, so that in a vertical section they have something of an hour-glass form. The crater-like walls are all the time melting, and the morainal material which forms the upper two or three feet of their rims, is undermined and slides and rolls down the steep slopes, and accumulates in the basins below. These lakes last from year to year, but are finally drained, usually through a crevasse or opening of some sort at the bottom, and the basins are left with a deep filling of bowlders and stones. As the general surface of the glacier melts away, the ice beneath these thick accumulations of debris is protected and left in relief as the less deeply covered surface melts. The debris is thus raised on a pedestal, but does not behave like a single great bowlder. It slides away in all directions and a pyramid of ice sheathed with debris is the result. What was a crater-like depression, possibly seventy-five or a hundred yards across and a hundred feet deep, becomes in this way a pyramid fifty or sixty feet high. These pyramids are of the nature of the sand cones so common on many glaciers which are covered with light moraines, but instead of being annual as are most sand cones, they are perennial and only pass through their cycle of change once in several years. The alternate formation of lake basins and of debris pyramids, has an important effect in breaking up the stones and bowlders of which the moraines

resting on the stagnant glaciers, are composed. The rolling and sliding of the debris down the sides of the lake basins as they enlarge, and from the steep sides of the debris pyramids as they waste away, cause it to become more and more broken.

While traveling over the moraine-covered surfaces of the stagnant portions of the glaciers, especially on bright sunny days or when rain is falling, one is constantly startled by the rattle of stones and bowlders as they roll down the steep walls of the lakelets and plunge with a great splash into the muddy waters below.

This constant movement in the moraines whereby the blocks of which they are composed are broken finer and finer, is confined principally to the stagnant portions of the glaciers. When the glaciers are moving, lakelets cannot form for the reason that their basins become broken, and the water escapes.

Forests on the Moraines.—The outer and consequently older portions of the fringing moraines, are covered with vegetation, which in places, particularly near the outer margin of the belt, has all the characteristics of old forests. It consists principally of spruce trees some of which are three feet in diameter, and cottonwood, alder, and a great variety of shrubs and bushes, together with rank ferns which grow so densely that one can scarcely force a passage through them. The vegetation grows on the moraines resting on the ice, which in many place is not less than a thousand feet thick.

The vegetation is confined principally to the border of the Seward lobe. Near Icy bay it forms a belt five miles broad, but decreases in width toward the east, and is wanting at the Sitkagi bluffs, where the glacier is being eaten away by the sea. This is an interesting fact, for the reason that on the maps of this coast published by Vancouver, a cape is indicated at the locality where the glacier now comes down to the ocean. Evidently the cape has been cut away during the past one hundred years, and the recession has progressed until the forest covered border of the glacier has been removed. The forests appear again on the margin of the glacier to the east of Sitkagi bluffs, and also on the north border of the glacier. But on the portion adjacent to Yakutat bay it is wanting; the flow of the ice is toward Yakutat bay, which probably accounts for the absence of vegetation on that portion of the glacier. It is only on the stagnant border of the ice sheet that forests occur. The forest-covered area is by estimate, between twenty and twenty-five square miles in extent.

Drainage.—The drainage of the Malaspina glacier is almost entirely inter glacial or sub-glacial. There is no surface drainage, excepting in a few localities where there is a surface slope,

but even in such places the streams are short and soon plunge into a crevasse or a moulin and join the drainage beneath.

On the lower portions of the Alpine glaciers, tributary to the Malaspina, there are sometimes small streams coursing along in ice channels, but they are short-lived. On the borders of these tributaries there are frequently important streams, flowing between the ice and a mountain slope, but where these come down to the Malaspina, they flow into tunnels and are lost to view.

Along the southern margin of the Malaspina glacier, between the Yahtse and Point Manby, there are hundreds of streams which pour out of the escarpment formed by the border of the glacier, or rise like great fountains from the gravel and bowlders at its base. All of these streams are brown and heavy with sediment and overloaded with bowlders and stones.

One of the largest streams draining the glacier is the Yahtse. This rises in two principal branches at the base of the Chaix hills, and flowing through a tunnel some six or eight miles long, emerges at the southern border of the glacier as a swift, brown flood, fully one hundred feet across and fifteen or twenty feet deep. The stream after its sub-glacial course, spreads out into many branches, and has built up an alluvial fan which has invaded and buried thousands of acres of forest. In traversing the coast from the Yahtse to Yakutat bay, we crossed scores of ice water streams which drain the ice field to the north. The greater part of these could be waded, but some of them are rivers which it was impossible to ford.

The most interesting of these is Fountain stream. This comes to the surface in one great spring fully one hundred feet across. The water rises under such pressure that it is thrown twelve or fifteen feet into the air, and sends up jets of spray six or eight feet higher. It then rolls seaward, forming a broad, swift river which divides and spreads out in many channels both to the right and left and has inundated several hundred acres of forest land with gravel and sand. Where the streams flowing away from the glacier are large, they divide as do the Yahtse and Fountain, and enter the sea by several mouths. When they are small, they usually unite to form large rivers before entering the ocean. The Yahtse and Fountain, as we have seen, are examples of the first, while Manby stream is an example of the second class. This rises in hundreds of small springs along the base of the escarpment formed by the great glacier, and flowing across a desolate torrent-swept area, unite just before reaching the ocean into one broad swift flood of muddy water, much too deep for one to wade.

All of the streams where they leave the glacier are overloaded and at once deposit the coarser portions of their burdens. Those which bifurcate, continue to build up their channels all the way to the sea; while the rivers, formed by the union of many small branches, excavates channels, the depth of which is regulated by the elevation of the land above sea level. All of the streams bear quantities of debris to the ocean, but there their work ends. The waves and currents in the ocean seize the debris delivered to them and build it into beaches and bars. Nearly all of the streams near their mouths are turned westward on account of sand bars thrown across them by the prevailing ocean currents. Nothing of the nature of stream channels beneath sea level is suggested, or could reasonably be expected.

On the border of the glacier facing Yakutat bay the drainage is different from that on the southern border. The flow of the ice is there eastward and instead of forming a bold, continuous escarpment, ends irregularly with a low frontal slope.

The principal streams on the eastern margin in 1891, were the Osar, Kame and Kwik. Each of these issues from a tunnel and then flows for some distance between walls of ice. Of the three streams, mentioned, the most interesting is the Kame. This issues from the mouth of a tunnel in the ice about three miles back from the actual border of the glacier, and flows for half a mile in a narrow cañon with walls of dirty ice fifty feet or more high. The cañon then expands and forms a valley bordered by moraine-covered hills of ice, which gradually widens toward the east, until it merges with a low marshy tract bordering the shore of the bay. Well rounded sand and gravel is being deposited by this stream in large quantities. This covers the ice over which the stream flows, and during former stages, was deposited in terraces along the lower portion of the channel. These terraces, in part at least, rest on ice. The rounded and worn condition of the gravel and sand brought out of the tunnel, is proof that it has had a long interor sub-glacial journey.

On the north side of the open channel of Kame stream there is a sharp ridge of well rounded gravel which runs parallel with the present river, and in places can be seen to rest on an icy bed. This was evidently deposited by a stream similar to the present one, but which flowed fully one hundred feet higher. This ridge of gravel seems to be of the same general character as the Kames of New England and other glaciated regions.

Near the shore of Yakutat bay, Kame, Osar and other streams of the same character, spread out in lagoons and sand flats, where the finer material which they carry is deposited.

Sometimes this debris is spread out on the ice, and forms level terraces of sand and mud, which become prominent as the glacier wastes away.

The formation of osars seems fully explained by the subglacial drainage of the Malaspina ice sheet. On the north side of the glacier there are many streams which flow into tunnels and carry with them large quantities of gravel, sand and mud; while on its southern and eastern margin many streams emerge from tunnels and bring out large quantities of water-worn debris. The openings of the tunnels on the outer margin of the glacier, are choked with debris, the coarser part of which, as already stated, is deposited as soon as the streams have an opportunity to expand and bifurcate. With the material swept out of the tunnels there is also deposited many large bowlders as well as much small angular debris, contributed by the moraines resting on the margin of the ice. The deposits formed by the streams below the mouth of the tunnels from which they emerge, have the form of low cones, which are being built up rapidly at the apex, and consequently expand at the same time in all directions. In expanding they frequently invade and bury large areas of forested country, as already noticed in the case of the Yahtse. It is evident that so long as the margin of the Malaspina glacier remains stationary or retreats, the alluvial cones about its outer margin will continue to grow. This much of the genesis of these accumulations is a matter of observation, and affords data for judging of the character of the deposits that are being formed in the tunnels through which the glacier is drained.

The growth of the alluvial cones described above, tends to obstruct the flow of water through the tunnels connecting with them, and must cause the streams to deposit a portion of their load on the bottoms of the channels which they occupy. The water is thus brought in contact with the ice forming the roofs of the tunnels, which is melted away and gives room for a farther increase in the thickness of the subglacial stream-deposits. In the case of a stagnant ice-sheet the accumulation of gravel in the tunnels by which it is drained, would continue to increase until the water finds new channels. In this way deep narrow deposits of cross stratified gravel might be formed within a glacier, which when the ice melted would assume an anticlinal structure, owing to the displacement of the material along its sides.

In this brief digression, I have not attempted to give a complete analysis of the subglacial drainage of the Malaspina glacier; but simply endeavored to show that the tunnels through which it is drained, must be occupied in part by

gravel deposits, similar in many ways to the long, winding ridges to which the name *osar* has been applied.

Marginal lakes.—Along the northern margin of the Malaspina glacier wherever a mountain spur projects into the ice, the rocks become warmed, and radiating heat, causes the adjacent border of the glacier to melt away. This forms a valley which becomes a line of drainage. When the streams, following the sides of a mountain spur projecting into the glacier, come together, a lake is formed which discharges through a tunnel in the ice. When the glacier passes the mouth of a lateral valley the drainage is checked and a lake formed. There are several lakes of this character about the Chaix hills. There are other methods by which the great glacier acts as a dam and cause lakes to form, but we have not time to trace out all of their histories.

These marginal lakes on the north side of the Malaspina glacier are situated at an elevation of from a thousand to fifteen hundred feet on the sides of the mountains, and receive the debris brought down by tributary streams, which is built into deltas and terraces. When the glacier melts away these deposits will be left as irregular terraces on the mountain side. Lakes will be formed about the same mountain spurs, again and again, as the surface of the ice is lowered, thus making an irregular record with considerable vertical range. It seems to me that similar records should be found on the southern slopes of the mountains of New England, and other regions, which were formerly covered by ice-sheets, analogous to the Malaspina glacier.

Photographs of the magnificent scenery of the St. Elias region were exhibited at the close of the lecture.

Art. XXI.—*Hudson River "Fiord"*; by Arthur M. Edwards, M.D.

I have been for sometime investigating the deposit thrown down during the Champlain period in the Hudson River, New York, more especially to find out if it is the same as that of the bay of Newark, N. J., and I have decided that they are different; that of Newark being newer than that of the Hudson River. But I have been called upon to examine the soundings from the Hudson River "Fiord" made by Mr. A. Lindenkohl of the U. S. Coast Survey which he has kindly furnished to me and they are with the following results. In

lat. 39° 34′, long. 72° 26′, depth 168 fathoms there were found *Achnanthes brevipes* C. A. A., *Actinocyclus Ehrenbergii* J. R. with three rays (*A. ternarius* C. G. E.) and with five rays (*A. quinarius* C. G. E.), *Actinoptychus undulatus* J. W. B., *Chætoceros Wighamii* T. B., *Cocconeis scutellum* C. G. E., *Coscinodiscus lineatus* C. G. E, *C. minor* C. G. E., *C. oculus-iridis* C. G. E., *C. radiatus* C. G. E., *C. subtilis* C. G. E., *Cyclotella operculata* F. T. K., *Dictyocha fibula* C. G. E., *D. spicula* C. G. E., *Denticula palea* D. C. L. N., *Epithemia Jurgensii* C. A. A., *Goniothecium anaulus* C. G. E., *Gaillionella granulata* C. G. E., *Hyalodiscus stelliger* J. W. B., *Navicula elliptica* F. T. K., *Synedra ulna* D. C. L. N., *Triceratium alternans* J. W. B., *T. favus* C. G. E., *T. reticulum* C. G. E.,—*Foramenifera*, *Polycistina*. In lat. 39° 32′, long. 22° 8′, depth 261 fathoms, there were found *Actinocyclus undulatus* J. W. B., *Actinoptychus Ehrenbergii* J. R., *Coscinodiscus eccentricus* C. G. E., *C. oculus-iridis* C. G. E., *C. radiatus* C. G. E., *C. subtilis* C. G. E., *Cyclotella Kutzingiana* G. H. K. T., *C. operculata* F. T. K., *Chætoceros Wighamii* T. B., *Denticula palea* D. C. L. N., *Dictyocha fibula* C. G. E., *Doryphora amphiceros* C. G. E., *Gaillionella granulata* C. G. E., *G. sulcata* C. G. E., *Navicula elliptica* F. T. K., *Synedra* ——*?*, *Triceratium alternans* J. W. B.,—*Sponge spicules*, *Polens pirni*. In lat. 39° 56′, long. 72° 11′, depth 47½ fathoms there were found *Actinocyclus undulatus* S. W. B., *Gaillionella sulcata* C. G. E.,—Sponge spicules. In 43 fathoms between the fiord and Montauk Point *Actinocylus undulatus* S. W. B., *Coscinodiscus oculus-iridis* C. G. E., *C. radiatus* C. G. E., *Gaillionella granulata* C. G. E., *G. sulcata* C. G. E., *Pinnularia peregrina* C. G. E., *P. viridis* D. C. L. N., *Triceratium alternans* J. W. B., *T. reticulum* C. G. E.,—Sponge spicules. As these species are the same, or rather the grouping of them, as are living on the coast we may consider this as made up the recent forms. There is also present besides quartz sand, which makes up the mass of the soundings, broken crystals of magnetic oxide of iron and transparent green crystals of hornblende showing that they come from the Palisades of New Jersey or the Trap rocks of Connecticut, most likely of Connecticut, for this is the way north or somewhat to the east, the ice came which formed the moraine on the coast. The microscopic organisms are not those of the Newark bay as they are not of brackish or fresh-water origin as those are, showing the "fiord" is not a continuation of Newark bay but rather of the Hudson River. This may serve as a contribution to the knowledge of the Hudson River "fiord."

ART. XXII.—*Contributions to Mineralogy, No.* 52; by F. A. GENTH. *With Crystallographic Notes;* by SAMUEL L. PENFIELD.

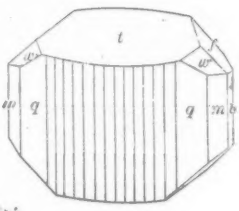
1. *On Hübnerite.*

a. FROM the North Star Mine, Sultan Mountain, Silverton, San Juan Co., Col.

The specimens which were used for crystallographic examination were from the private collection of Mr. Geo. L. English, of New York. The occurrence of well terminated hübnerite crystals is not without interest, as our knowledge of the crystallization of this species is at present confined to a description, by Professors P. Groth and A. Arzruni,* of artificial crystals. These were not sufficiently developed to admit of an accurate determination of the crystallographic constants, although the authors were able to show a close similarity in form and angles between artificial $MnWO_4$ and $FeWO_4$ and the mineral wolframite $(Mn, Fe)WO_4$.

The ore, in which the hübnerite occurs, consists mostly of quartz with galena, pyrite and tetrahedrite disseminated through it. Cavities are lined with drusy quartz and contain crystals of hübnerite, tetrahedrite and occasionally very pretty rhombohedrons of rhodochrosite. The hübnerite usually occurs in groups of radiating and divergent, long-prismatic crystals; these are often coated with a thin layer of drusy quartz, which sometimes can be removed, by gentle pressure, leaving the prismatic faces smooth and glistening but as the faces at the termination of the crystal are usually rough, the quartz coating adheres there more tenaciously. On one specimen, groups of these long-prismatic crystals, covered with quartz, were found in one cavity, while in another, less than two inches removed, short-prismatic, doubly terminated and isolated crystals were found, which were not coated and which served for accurate crystallographic measurement. These crystals, which measure about 4 mm. in the direction of the ortho-axis, have the habit shown in the accompanying figure. The forms which were observed are:

b, 010, $i\text{-}\bar{1}$	*t*, 102, $-\frac{1}{2}\text{-}\bar{1}$
m, 110, I	*f*, 011, $1\text{-}\bar{1}$
q, 830, $i\text{-}\frac{\bar{3}}{8}$	ω, 111, -1



* Pogg. Ann., cxlix, p. 236, 1873.

Of these, the only faces which were suited for exact measurement were m and f; b was bright but, owing to a fine vertical striation, it gave a multiple reflection of the signal on the goniometer. By taking advantage, however, of the perfect clino-pinacoid cleavage, a face parallel to b was developed, which gave a single reflection and, when tested on the goniometer, exactly truncated the prism m. The measurements from these faces, which were taken as fundamental are:

$m \wedge m$,	$110 \wedge \bar{1}10$	$= 100° 12'$
$f \wedge m$,	$011 \wedge \bar{1}10$	$= 65° 43'$
$f \wedge b$,	$011 \wedge 010$	$= 49° 5'$

from which the following axial ratio was calculated:

$$\dot{a} : \bar{b} : \dot{c} = \cdot 83623 : 1 : \cdot 86684, \beta = 100 \wedge 001 = 89° 7\tfrac{1}{2}'$$

The axial ratio established by Des Cloizeaux* for wolframite is;

$$\dot{a} : \bar{b} : \dot{c} = \cdot 83000 : 1 : \cdot 86781, \beta = 89° 22'$$

Besides the measurements given above as fundamental, the only accurate measurement which could be made was

$$f \wedge m, 011 \wedge 110 = 64° 32' \text{ calculated } 64° 36'$$

The faces in the prismatic zone are usually vertically striated. This is especially true of q, the obtuse edge of which is rounded as indicated in the figure. Owing to these striations, no exact measurements could be obtained from q; however, the symbol given above agreed best with the measurements and, as will be shown later, this prism is prominent on crystals from another locality. Possibly a pinacoid a, 100, i-$\bar{i}$, oscillates with q but no distinct reflection was obtained from the striated part to indicate its existence. With the exception of f, the faces which terminate the crystals are usually poorly developed; ω was determined by approximate measurements only; t usually gave no reflection whatever.

Cleavage sections, parallel to b, show with the polarizing microscope an extinction, inclined about 17° from the vertical axis, in the obtuse angle β. This direction corresponds to the axis of least elasticity c. In convergent polarized light an obtuse bisectrix could be seen, but the section was too small to admit of a measurement of the angle of the optical axes. The sections transmit a brown light. The pleochroism is marked; for rays vibrating parallel to c green; parallel to b yellowish brown, but varying somewhat, even in the same section. An increase of color is probably due to a slight percentage of FeO, the lighter colored material is probably nearly pure $MnWO_4$.

* Ann. Chimie et Phys., IV, xix, p. 168, 1870.

Some groups of radiating crystals of a brownish yellow color, not over 2^{mm} in diameter have been noticed, which probably are also hübnerite.

An analysis of the radiated variety of a brownish black color, yielding a pale grayish brown powder, and having the specific gravity 6·713 gave, after deducting 3·608 per cent quartz:

WO_3	74·75
FeO	2·91
MnO	21·93
CaO	0·11
MgO	trace.
	99·70

b. From Cement Creek on Bonita Mountain near Silverton, San Juan Co., Colorado.

This variety we have not been able to obtain in isolated crystals. It is associated with quartz and pyrite and occurs in a radiating and divergent mass, up to 40 to 50^{mm} in length, with distinct clino-pinacoid cleavage. Color hair-brown to reddish and yellowish brown, in thin splinters transparent, luster submetallic, inclined to silky. The fine powder is of isabella color. Sp. gr.=6·891.

The analysis gave, after deducting 2·4 per cent of quartz:

			Harry F. Keller.*
WO_3	76·63		76·14
FeO	1·61	−1·63	2·11
MnO	21·78		21·63
CaO	0·09		0·12
MgO	trace		trace
	100·11		100·00
			Sp. gr.= 6·780

c. From Bonito Mountain near White Oakes, Lincoln Co., N. M.

This variety occurs in fissures in granite. The crystals are long prismatic and for the most part coated with drusy quartz. The prismatic faces are usually vertically striated, but a few crystals were found which gave very good reflections. In the prismatic zone *b*, *m* and *q*, were observed, but *q*, which is new, was the most prominent. The symbol 830, $i\text{-}\frac{8}{3}$, approximates to 310, $i\text{-}\bar{3}$, which has been observed on wolframite, but four independent measurements, where the reflection from *q* were sharp and distinct, gave $q \wedge b = 72° 55'$; $72° 46'$; $72° 41'$ and

* After deducting 2·13 per cent of quartz, the analysis of Harry F. Keller of the same variety (megabasite from Bonita Mountain near Silverton, Col., in Franklin Institute Journal, August, 1889), gave the above composition.

72° 21′, average 72° 41′, calculated for 830 ∧ 010 = 72° 35½′, while for 310 ∧ 010 the calculated angle is 74° 26′. The crystals are usually terminated by *t*, or by *t* and a pyramid *Δ*, 112, in the zone *t*, *b*. The dome *t* was either dull or had a sort of undulatory surface, so that it gave no distinct reflection. The pyramid *Δ* gave only faint reflections and yielded the following measurements.

	Measured.	Calculated.
Δ ∧ *b*, 112 ∧ 010 =	68° 51′ and 69° 20′	69° 4½′
Δ ∧ *q*, 112 ∧ $\bar{8}$30 =	108° 28′	108° 14

Only the thinnest cleavage splinters of this material were at all transparent, so that no attempt was made to study the optical properties.

Color iron black to brownish black, luster submetallic, inclining to adamantine. Powder greenish gray. Sp. Gr. = 7·163 – 7·091.

The analysis gave, after deducting 0·34 per cent of quartz:

	I. Lincoln Co., N. M. (Genth.)	II. Mammoth Dist., Nevada.
WO_3	76·33	74·88
FeO	3·82 — 3·98	0·56
MnO	19·72 — 20·08	23·87
CaO	0·13	0·14
MgO	trace	CuO 0·08, 0·08
	100·00	99·61

d. **From Monmouth District, Nye Co., Nevada.**

For comparison we have examined the hübnerite from Riotte's original locality. The specimens at our disposal showed no distinct crystals but only cleavage masses, implanted on quartz. Color brownish black to iron-black, powder greenish-gray. A little of the manganese is higher oxydized, as the mineral evolved some chlorine, when treated with hydrochloric acid. The analysis is given under II above

2. *Hessite from Mexico.*

Prof. Carlos F. de Landero of Guadalajara kindly presented a specimen of hessite from a recent occurrence at the Refugio Mine, San Sebastian District, State of Jalisco, Mexico, which was analyzed by Mr. Jas. S. de Benneville. It is granular, of a dark lead gray color, and so very largely and intimately intermixed with quartz, that no pure material could be picked out for analysis. The composition of the mixture was found to be

SiO_2	33·33		
Al_2O_3	0·70		
CaO	0·49		
Fe	0·16		
Cu	trace		
Pb	1·21	equivalent of Te	0·75
Ag	39·42	" "	23·38
Te	25·53		24·13
Se	trace		
	100·84		

This would represent: 62·80 per cent Ag_2Te, 1·96 per cent PbTe with 1·40 per cent of tellurium, which may be present as native tellurium or perhaps as tellurous oxide. The presence of some incrustations, resembling tellurite, would indicate that the latter supposition is probably the correct one.

3. *Bismutite.*

Associated with the phenacite of Mount Antero in Chaffee County, Colorado, are quartz, orthoclase, scales of muscovite, hematite, and a grayish or yellowish green bismuth mineral in prismatic form. The hematite occurs in small brilliant crystals, the largest not over 4^{mm} broad and about $1·5^{mm}$ thick, the combination being short prisms terminated by a flat rhombohedron. Of the bismuth mineral only one fragment of a crystal was observed of a darker greenish color and having angles agreeing with the sulphide Bi_2S_3, from the alteration of which it probably had been derived. Other small crystalline masses were observed, resembling bundles of deeply striated crystals, the largest about 30^{mm} in size, but, unfortunately, throughout the whole mass, contaminated with salts of lead, copper, zinc, ferruginous clay, etc. Examining the association it appears that quartz, muscovite in hexagonal plates and hematite are the oldest, after which the bismuth mineral was deposited, and upon this, the most recent phenacite, which frequently is found upon the bismuth mineral and between its fissures,—or the phenacite has crystallized around fragments of the same.

It was impossible to obtain the bismuth mineral in a state of purity. The best gave the composition given below, after deducting in analysis I, 5·11 per cent of impurities, such as hematite, muscovite and ferruginous clay—in analysis II, 4·22 of the same.

The sp. gr. of the material for analysis was found to be: 6·293, while the darker greenish crystal yielded: 7·330. The analyses gave:

	I		II	
	a	*b* Less impurities	*a*	*b* Less impurities
Impurities ..	5·11		4·22	
[Ignition, 9·18]				
H_2O	2·02	2·11	2·33	2·43
CO_2	7·16	7·47	6·85	7·14
CuO	0·31	0·32	0·32	0·33
PbO	4·83	5·04	4·63	4·82
Bi_2O_3	80·13	83·64	80·41	83·81
ZnO	0·86	0·90	0·86	0·89
SO_3	0·50	0·52	0·56	0·58
	100·92	100·00	100·18	100·00

The lead is probably present as $PbCO_3$ and $PbSO_4$, the copper as malachite, the zinc as $ZnCO_3$ and the bismuth as hydrated-carbonate, but the material is too impure to attempt the construction of a formula.

4. *Natrolite.*

Associated with aegirite, eudialyte, titanite, etc., natrolite occurs at Magnet Cove, Ark., in large colorless, cleavable masses, the individuals being about 50^{mm} in length and $5{\cdot}8^{mm}$ broad. The cleavage, although apparently perfect, does not yield good surfaces for reflecting light. The angle between the cleavages is very near 90°, but most of the measurements which were made are near 91° and 89°. The crystals are colorless, some portions, however, are more or less opaque. It was found that the latter contain a minute quantity of lime, while the colorless portion is free from it. The spec. gravity was found to be 2·243. The analysis gave:

H_2O	9·81
SiO_2	47·97
Al_2O_3	26·51
Na_2O	15·98
	100·27

Chemical Laboratory, 111 S. 10th St.,
Philadelphia, October 25th, 1891.

Art. XXIII.—*Tschermak's Theory of the Chlorite Group and its Alternative;* by F. W. Clarke.

In the micas, vermiculites, the clintonite group, and the chlorites, we meet a large number of minerals having similar properties. All are probably monoclinic, all are commonly foliated in structure, and within certain limits they shade into each other in composition. The resemblances between them are very close externally; and it is therefore a fair presumption that they are also alike in constitution. A satisfactory explanation of their chemical structure ought to emphasize their obvious relationships, and be sufficiently general to include all the individual species in a single definite theory. The problem is easily stated, but its solution can be effected only by slow degrees. Like other similar problems, it must be solved by a series of approximations; and every step towards order is a gain, even though it be not absolutely final.

Among the men who have advanced our knowledge of these minerals, no one is entitled to higher credit than Professor Tschermak. His successive papers upon the mica, clintonite, and chlorite groups have all been long strides forward; and whether his interpretations are ultimately confirmed or abandoned, they have none the less been of real service in the development of knowledge.

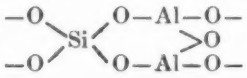
In his latest paper,* Professor Tschermak seeks to explain the chemical structure of the chlorites, and masses the available evidence most admirably. This group of minerals he divides into two sub-groups, called orthochlorites and leptochlorites respectively, and for each division a special explanation is offered. The orthochlorites, which include pennine, clinochlore, leuchtenbergite, prochlorite and corundophilite, are simply represented as mixtures of two end products, serpentine and amesite; and so far as the mere ultimate composition of the minerals is concerned, the interpretation is quite satisfactory. On theoretical grounds it leaves something to be desired, as will appear later. The leptochlorites, however, or chlorites outside of the main series, are less easily handled; and for these, in addition to the serpentine and amesite molecules, four other fundamental compounds are assumed; namely, two derivatives of amesite, strigovite and chloritoid. Six types of molecule are in all adopted; which, by mixtures in various proportions account for all the species. Written semi-empirically, these molecules are as follows:

* Die Chloritgruppe, II, Theil, Sitzungsb. Akad. d. Wiss. in Wien, 19 Feb., 1891.

Serpentine,	Sp.	$MgSi_2O_7 . H_2 . (MgOH)_2$
Amesite,	At.	$Al_2SiO_7 . H_2 . (MgOH)_2$
" 1st deriv.,	At′.	$Al_2SiO_7 . H_2 . MgOH$
" 2d "	At″.	$Al_2SiO_7 . H_4$
Strigovite,	St.	$SiO_2 . Al_2SiO_7 . H_2 . (MgOH)_2$
Chloritoid,	Ct.	$Al_2SiO_7 . H_2 . Mg$

Of these compounds, four are represented by known minerals; although the amesite and strigovite formulæ rest each upon a single analysis. Two, the molecules At′ and At″, are hypothetical. Empirically, all the chlorites of well established character correspond in composition to mixtures of these six molecules; but a few of the allied minerals, such as epichlorite and stilpnomelane, are unaccounted for. The latter are yet to be brought into line.

At a first glance the six molecules, as just written, appear to be remarkably alike in form. But when they are written structurally, as Tschermak himself writes them, they become somewhat dissimilar. Serpentine is then represented as a salt of the acid $H_6Si_2O_7$. Amesite, with its two derivatives and chloritoid, appear as basic orthosilicates. Strigovite is given as a salt of the acid $H_4Si_2O_6$. That is, three different silicic acids are involved in Tschermak's theory, and the first apparent simplicity of the scheme disappears. All of the six molecules, however, with the single exception of the non aluminous serpentine, are supposed to contain the structural nucleus



to which the remarkable similarities of the chlorites may be due. Through chloritoid the chlorites become affiliated with the clintonite group; but with the micas, at least as the latter have been interpreted by Tschermak hitherto, no special analogies of structure appear.

Now, admitting that Tschermak's theory accounts for the known facts as fully as he believes, the question arises whether his mode of interpretation is the only one possible. If it is, then the problem of the chlorite group is solved, and controversy is out of court. But if other schemes can be devised, representing the facts equally well, further investigation becomes necessary. Pending the acquirement of new experimental evidence, we may discuss rival systems upon philosophic grounds; and that which is simplest, most general, and best supported by analogies, should have preference. Ultimately, of course, the problem must be attacked by means of experiment; through which alone the questions at issue can be finally settled.

In several previous papers, some of them written in joint authorship with others,* I have sought to establish the hypothesis that the more complex silicates are merely substitution derivatives of normal salts. For instance, many minerals are easily and naturally represented as so derived from the normal aluminum compound $Al_4(SiO_4)_3$; successive aluminum atoms being equivalently replaced by other atoms or groups. Among these minerals, the micas seem to form a conspicuous family, and with them are found the clintonite group and some vermiculites. To this family I shall recur later.

In two quite recent papers, Schneider and I have tried, by experimental methods, to obtain some positive evidence as to the nature of the chlorites. That our results are not final, and that Tschermak's criticism of them is perfectly legitimate, I cheerfully concede, and yet we have found clues which are not without meaning. The reaction between dry hydrochloric acid and the hydromagnesian silicates we are still investigating, and its actual character and significance we hope to determine in due time. So far, however, in every case of a true chlorite examined by us, and in the case of serpentine also, we have found that the chemical constitution *may* be represented by a mixture of molecules of the general form $Mg_2(SiO_4)_2\ R'_4$, in which R′ may be either AlH_2O_2, MgOH, or H, with of course the usual equivalent replacements of aluminum and magnesium by ferric and ferrous iron. These molecules are evidently substitution derivatives of the normal compound olivine, when the ordinary formula of the latter is doubled and made $Mg_4(SiO_4)_2$. Since we do not know the true molecular weight of any metallic silicate, this doubling of the simplest possible formula is perfectly allowable, and a reason for it will appear later. Here then, for a few chlorites at least, is a scheme of interpretation quite unlike Tschermak's; and we have to determine whether it is equally exact and equally general.

Taking Tschermak's paper as a basis for comparison, and discussing at first only the analyses discussed by him, I find that all of his orthochlorite series, except corundophilite and amesite, reduce sharply to the above given type of formula. Omitting amesite, which will be separately considered further on, every orthochlorite may be written $R''_2(SiO_4)_2R'_4$, with various relations between the several components collectively represented by R'_4. In fact, Tschermak's formulæ and mine, although quite dissimilar, are curiously parallel; as the following scheme, based upon his classification of the orthochlorites, plainly shows. His arrangement of the sub-group is this:

*See U. S. Geological Survey Bulletins, numbers 27, 42, 60, 64 and 78. Also this Journal for Sept., 1891.

Pennine,	Sp_5At_5 to $SpAt$
Clinochlore,	$SpAt$ to Sp_2At_3
Prochlorite,	Sp_2At_3 to Sp_3At_7
Corundophilite,	Sp_3At_7 to $SpAt_4$

Transforming these expressions, and, for brevity, writing $AlH_3O_3 = A$, and $MgOH = M$, we have:

$Sp_5At_5 = Mg_5(SiO_4)_5 \cdot A_4M_5H_7 = {}_nMg_2(SiO_4)_2R'_4$
$SpAt = Mg_2(SiO_4)_2 \cdot A_2M_2H_2 =$ "
$Sp_2At_3 = Mg_7(SiO_4)_7 \cdot A_6M_3H_3 =$ "
$Sp_3At_7 = Mg_{13}(SiO_4)_{13} \cdot A_{14}M_{10}H_2 =$ "
$SpAt_4 =$ appproximate agreement only.

In the last case, corundophilite, Tschermak's formula agrees better with the actual analyses than any formula derived from my system. The cause of divergence will be considered in connection with the structure of amesite, later. Although the difference is small it ought not to be ignored.

In general, then, the orthochlorites may be provisionally regarded as mixtures of the three typical or generic salts $Mg_2(SiO_4)_2A_4$, $Mg_2(SiO_4)_2M_4$, and $Mg_2(SiO_4)_2H_4$. Whether these compounds exist separately in the mineral kingdom is an open question, and one not easy to answer. To each of them there are approximations; ekmannite for example is near $Fe_2(SiO_4)_2H_4$ in composition; but it is more probable that the chlorites proper are mixtures of intermediate salts. Some pennines, for instance, fall near the compound $Mg_2(SiO_4)_2AMH_2$; and other like substances appear among the minerals which Tschermak places in the subgroup of leptochlorites. A consideration of the latter must precede further discussion of theory.

According to Tschermak, the leptochlorites form three subgroups, as follows:

I.	Daphnite,	$At_3At'_3Sp$
	Chamosite,	$At_2At'_3Sp$
II.	Metachlorite,	$At_6St_2Sp_3$
	Klementite,	At_4St_2Sp
	Cronstedtite,	$AtSt$
	Thuringite,	$AtSt$
	Euralite,	At_3St_4
	Strigovite,	St
III.	Diabantite,	Ct_4Sp_7
	Aphrosiderite,	$Ct_6At_6Sp_4$ to $Ct_2At_6Sp_4$
	Delessite,	$Ct_2At_2Sp_6$ to $CtSp$
	Rumpfite,	$Ct_4At'_4Sp$

Epichlorite, grengesite, melanolite, etc., he regards as chlorites, but as not yet definable. The delessite from Friedrichsroda he places provisionally in the first division of the leptochlorites, along with daphnite and chamosite. The formulæ given are deduced from specific analyses, but when several

analyses exist for a species, a considerable variability becomes manifest, which must influence all attempts to fix the molecular structure.

Taking now the analyses as cited by Tschermak, a number of them reduce at once to the same type of substitution formula as that which I have assigned to the orthochlorites. Uniting like oxides, Fe_2O_3 with Al_2O_3, MgO with FeO, etc., we get at once the following expressions from the analytical data. The name of the analyst follows the name of the species:

Daphnite,	Zeynek,	$Fe''_{39}(SiO_4)_{40} \cdot H_{16}A_{44}M_{22}$
Chamosite,	Boricky,	$Fe''_{42}(SiO_4)_{43} \cdot H_{29}A_{37}M_{22}$
Delessite,	Pufehl,	$Mg_{40}(SiO_4)_{50} \cdot H_{28}A_{40}M_{22}$
Thuringite,	Gintl,	$Fe''_{41}(SiO_4)_{39} \cdot H_{11}A_{49}M_{16}$
"	Keyser,	$Fe''_{44}(SiO_4)_{46} \cdot H_{12}A_{50}M_{11}$

An approximation to close agreement with theory is evident at a glance; but a better conception of the agreement may be obtained by calculation, using the following formulæ:

Daphnite,	$Fe_2(SiO_4)_2A_2(FeOH)_1H_1$
Chamosite,	" " "
Delessite,	1 $Fe_2(SiO_4)_2A_2(FeOH)_1H_1$
(Friedrichsroda)	3 $Mg_2(SiO_4)_2A_2M_1H_1$
	1 $Fe_2(SiO_4)_2H_4$
Thuringite,	3 $Fe_2(SiO_4)_2A_2(FeOH)_1H_1$
	1 $Fe_2(SiO_4)_2A_4$

To this list we may add the thuringite from Lake Superior, analyzed by Penfield and Sperry, which becomes $5Fe_2(SiO_4)_2(FeOH)_4 + 9Fe_2(SiO_4)_2A_4$. The analyses, reduced to typical form and to 100 per cent, as is usual, are as follows:

	Daphnite. Zeynek.	Chamosite. Boricky.	Delessite. Pufahl.	Thuringite. Gintl.	Thuringite. Keyser.	Thuringite. P. & S.
SiO_2	23·44	25·17	29·75	23·58	24·15	21·35
Al_2O_3	22·08	18·41	20·58	25·11	25·44	24·02
FeO	43·41	45·37	19·42	40·08	39·39	43·88
MgO	----	----	17·53	----	----	----
H_2O	11·07	11·05	12·72	11·23	11·02	10·75
	100·00	100·00	100·00	100·00	100·00	100·00

Calculated from the formulæ just given they become:

	Daph. & Cham.	Deless.	Thuring. G. & K.	Thuringite, P. & S.
SiO_2	24·39	30·30	23·81	21·54
Al_2O_3	20·73	20·60	25·30	23·54
FeO	43·90	18·18	39·29	44·31
MgO	----	18·18	----	----
H_2O	10·98	12·74	11·60	10·61
	100·00	100·00	100·00	100·00

In short, these chlorites are apparently compounds of precisely the same type as the orthochlorites. Daphnite and chamosite vary from theory by small amounts in opposite directions, the one having a trifling excess of an FeOH salt, the other an excess of an AlH_2O_2 compound. Closer agreements could not be reasonably expected.

In order to properly interpret the remaining leptochlorites, we must return to the fundamental idea of the substitution hypothesis. Starting with the normal ortho-salt, we get at once the following probable series of derivatives.

Olivine,	$Mg_4(SiO_4)_2$
	$Mg_3(SiO_4)_2R'_2$
Orthochlorites,	$Mg_2(SiO_4)_2R'_4$
	$Mg(SiO_4)_2R'_6$

In the first of these derivatives, the compound intermediate between the orthochlorite type and olivine, we find the key to most of the leptochlorites. Again discussing the analyses mainly considered by Tschermak, omitting strigovite and rumpfite for separate inspection, we get the subjoined semi-empirical expressions:

Metachlorite,	Zeynek,	$Fe''_{40}(SiO_4)_{40} \cdot H_{12}A_{41}M_{20}$
Euralite,	Wiik,	$Mg_{65}(SiO_4)_{66} \cdot H_{59}A_{32}M_4$
Diabantite,	Hawes,	$Mg_{69}(SiO_4)_{66} \cdot H_{53}A_{25}M_9$
Klementite,	Klement,	$Mg_{61}(SiO_4)_{48} \cdot H_7A_{36}M_7$
Delessite,	Heddle,*	$Mg_{75}(SiO_4)_{57} \cdot H_{39}A_{38}M_1 + 34$ aq.
Cronstedtite,	Ludwig,	$Fe_{49}(SiO_4)_{36} \cdot A_{44}$, nearly.
Aphrosiderite,	Rammelsberg,	$Fe_{54}(SiO_4)_{41} \cdot H_2M_8A_{44}$

Metachlorite, at one end of this series, corresponds nearly to the orthochlorites; while aphrosiderite, at the other end, approaches the composition $Fe_3(SiO_4)_2A_4$. All the other minerals in the series fall between these extremes. Reduced to general form, the expressions become:

Metachlorite,	$4R''_3(SiO_4)_2R'_4$	+	$1R''_3(SiO_4)_2A_2$	
Euralite,	7	"	+3	"
Diabantite,	4	"	+3	"
Klementite,	1	"	+1	"
Delessite,	1	"	+2	"
Cronstedtite,	1	"	+4	"
Aphrosiderite,	0	"	+1	"

These ratios, of course, are not rigidly exact, but they vary no more from the analyses considered than the analyses of the different occurrences in any one species vary among themselves. In the last case, the actual analyses show small admixtures of the orthochlorite type; but the approximation is

* The delessite from Bowling Quarry. The samples from Dumbuck and Long Craig agree well with this.

nevertheless quite close to theory. It will be seen that the value of R'_2 in the second term of each expression is constant; that is, that we have either AlH_2O_2 or the corresponding ferric radicle; but the values of the first term are somewhat different. In metachlorite, as in daphnite and chamosite, $R'_4 = A_2MH$; in cronstedtite it is A_4, and in delessite it is H_4. In klementite we have $R'_4 = A_3M$; in diabantite, $3R'_4 = M_4H_8$; and in euralite $7R'_4 = A_{22}H_6$. Such ratios, however, are difficult to fix sharply, because of the uncertainties in the water determinations. In Heddle's analyses, however, the water given off at 100° is distinguished from that retained at higher temperatures, and the results are correspondingly favorable to theory. In his delessite, for instance, the water becomes partly water of crystallization; and the mineral from Bowling Quarry agrees well with the formula $2Mg_3(SiO_4)_2A_4$, $2aq + Mg_2(SiO_4)_2H_4$; with about $\frac{2}{7}$ of the magnesium replaced by ferrous iron. Calculating the composition of each mineral from the formulæ given below, and comparing the results with the *reduced* analyses from which the expressions were derived, we can judge of the closeness with which the facts and the theory agree.

Metachlorite,	$4Fe_2(SiO_4)_2A_2(FeOH)H + Fe_2(SiO_4)_2A_2$
Euralite,	$7Mg_2(SiO_4)_2R'_4 + 3Mg_3(SiO_4)_2A_2$
Diabantite,	$4Mg_2(SiO_4)_2R'_4 + 3Fe_2(SiO_4)_2A_2$
Klementite,	$Mg_2(SiO_4)_2A_3M + Mg_3(SiO_4)_2A_2$
Delessite,	$Mg_2(SiO_4)_2H_4 + 2Mg_3(SiO_4)_2A_2, 2aq.$
Cronstedtite,	$Fe_2(SiO_4)_2(Fe''H_2O_2)_4 + 4Fe_3(SiO_4)_2(Fe''H_2O_2)_2$
Aphrosiderite,	$Fe_3(SiO_4)_2A_2$

	Metachlorite.		Euralite.		Diabantite.	
	Found.	Calc.	Found.	Calc.	Found.	Calc.
SiO_2	23·82	24·57	37·74	38·15	34·05	34·34
Al_2O_3	20·42	20·88	18·48	19·45	12·80	12·51
Fe_2O_3	----	----	----	----	----	----
FeO	45·76	44·23	----	----	26·32	26·49
MgO	----	----	30·91	29·24	16·70	16·35
H_2O	10·00	10·32	12·87	13·16	10·13	10·31
	100·00	100·00	100·00	100·00	100·00	100·00

	Klementite.		Cronstedtite.		Aphrosiderite.	
	Found.	Calc.	Found.	Calc.	Found.	Calc.
SiO_2	28·85	28·78	21·18	21·56	24·54	25·31
Al_2O_3	30·36	30·57	----	----	22·59	21·52
Fe_2O_3	----	----	35·74	34·48	----	----
FeO	----	----	35·19	36·20	43·87	45·57
MgO	28·73	28·78	----	----	----	----
H_2O	12·06	11·87	7·89	7·76	9·00	7·60
	100·00	100·00	100·00	100·00	100·00	100·00

Delessite.

	Found.	Calc.
SiO_2	34·00	33·83
Al_2O_3	19·34	19·17
MgO	30·24	30·08
H_2O	10·36	10·15
Aq	6·06	6·77
	100·00	100·00

In reducing the data, and in calculating the formulæ, I have commonly assumed R″ to be all magnesium or all iron according as one or the other predominated. Only in diabantite the relation between the Fe and Mg was so simple that it seemed desirable to keep both in view. I have also used relatively simple ratios between component molecules, rather than tne more complex terms which might give a closer agreement between analyses and theory. That is, when $Mg_2(SiO_4)_2R'_4$ and $Mg_3(SiO_4)_2A_2$ stood actually in the relation of 11 to 10, I have computed on the basis of 1 : 1. Most of the divergences between "found" and "calculated" are due to this cause; but in the case of cronstedtite, which is least concordant of all, there is probably a small admixture of some more basic compound, of the character, possibly, of amesite.

There now remains to be considered, of all of Tschermak's typical chlorites, only strigovite, rumpfite, amesite, and in part corundophilite. Of these, the first three depend each upon a single analysis, and the available evidence is therefore not conclusive. To strigovite, the general formula $H_4Fe''_2Al_2Si_2O_{11}$ seems to apply; which, in the constitutional expression given to it by Tschermak has already been cited. This may also be written $Fe_2(SiO_4)_2 . H(AlH_2O_2)(AlOH)$, which is of the orthochlorite type with the bivalent group AlOH in place of R'_2. In rumpfite, which has the empirical formula $H_{28}Mg_7Al_{16}Si_{10}O_{65}$, the same group AlOH appears, and also a molecule of the form of the last derivative of olivine, $Mg(SiO_4)_2R'_6$. In detail, rumpfite agrees very nearly with the composition

$$Mg_2(SiO_4)_2A_2H_2 + 2Mg(SiO_4)_2A_2(AlOH)_2;$$

which gives with the analysis by Firtsch redneed as usual, the following comparison:

Rumpfite.

	Found.	Calc.
SiO_2	31·01	30·20
Al_2O_3	42·02	42·79
MgO	13·73	13·42
H_2O	13·24	13·59
	100·00	100·00

It must be remembered that in order to account for rumpfite, Tschermak assumed the existence of the constituent molecule At″, which appears in none of his other chlorites. Both in his scheme and in mine the mineral is exceptional, and undoubtedly it needs further study.

In amesite, which occurs with corundophilite, we find another chlorite of peculiar composition. It is the most basic member of the group, and contains more oxygen relatively to its silicon, than any other chlorite known. Its formula, as written by Tschermak, is Al_2SiO_5, $H_2(MgOH)_2$, which is the equivalent of his serpentine molecule, with Al_2 in place of MgSi. As we have no experimental evidence from which to reason, we may with equal propriety regard amesite as having the structure

$$O<\begin{matrix}Mg\\Mg\end{matrix}>SiO_4 = (AlH_2O_2)_2;$$

when it becomes analogous in structure to the other chlorites, standing in a similar relation to them as that which the clintonite group bears toward the micas. On this supposition the micas and chlorites, as has already been shown elsewhere,* form two parallel series of compounds, as follows:

Normal orthosilicate,	$Al_4(SiO_4)_3$		$Mg_4(SiO_4)_3$
Whence derive—	*Micas*		*Chlorites*
Muscovite,	$Al_3(SiO_4)_2R_3$	Aphrosiderite,	$Mg_3(SiO_4)_2R_2$
Normal biotite,	$Al_3(SiO_4)_3R_6$	Orthochlorites,	$Mg_3(SiO_4)_3R_4$
" phlogopite,	$Al_3(SiO_4)_3R_9$		$Mg(SiO_4)_2R_6$
Clintonite,	$Al<\begin{matrix}O\\O\\SiO_4\end{matrix}>\begin{matrix}R''\\\equiv R_3\end{matrix}$	Amesite,	$O<\begin{matrix}Mg\\Mg\end{matrix}>SiO_4 = R_2$

In certain respects, this general scheme is not incompatible with Tschermak's views. The orthochlorites, for example, he regards as mixtures of serpentine and amesite, repesenting the structure of those compounds in a special way. But if serpentine be written $Mg_3(SiO_4)_2H_2(MgOH)$, and amesite as I have just suggested, the theory of substitution is satisfied, and the orthochlorites may be classified as intermediate between the two end terms. Then, however, the leptochlorites fall less easily into line, and the slight gain in apparent simplicity in the ortho series is offset by loss elsewhere. It is quite probable, however, that corundophilite is a mixture containing amesite molecules; and the formula which I give the latter mineral is sustained to some extent by the fact that both minerals occur intimately associated with diaspore. At Chester, the only locality for either corundophilite or amesite represented by analyses, the chlorites are commonly found in seams

* Clarke and Schneider, this Journal, Sept., 1891.

with diaspore on one side and emery on the other. Hence the group AlH_2O_2 is at least as likely to be found in amesite as the magnesian compound MgOH.

Still another analogy between the micas and the chlorites remains to be noted. In the phengitic muscovites, in some phlogopites and in the lithia micas, the ratio of silicon to oxygen is less than 1 : 4, and often approaches 1 : 3. This variability, as I have shown in my paper upon "A theory of the mica group,"* is easily explained by supposing an admixture of molecules containing the group Si_3O_8 in place of SiO_4. This equivalency is well recognized in the feldspar series; and among the micas it is forcibly emphasized by the existence of Lorenzen's polylithionite, in which the group Si_3O_8 replaces SiO_4 entirely. Does this group occur in chlorites also?

At the end of his discussion of the leptochlorites, Tschermak dismisses a number of minerals as doubtful in character, either because of unsatisfactory analyses, or uncertainty in the material described. In particular he names the species grengesite, hullite, melanolite and stilpnomelane, to which he adds epichlorite. All of these minerals, together with epiphanite and possibly strigovite, may be reduced to typical form by assuming the presence of Si_3O_8. For grengesite and hullite the analyses are not satisfactory, and the formulæ deducible have therefore no weight. Strigovite has been already explained by assuming in it the group AlOH, but a reconsideration here is worth noting as offering an alternative formula to that previously given. The formulæ which I have obtained are as follows:

Stilpnomelane, $\left\{\begin{array}{l} 4Fe_2(Si_3O_8)_2(FeH_2O_2)_2H_2 \\ +3Fe_2(SiO_4)_2(FeH_2O_2)_2H_2 \end{array}\right.$

Melanolite, $\left\{\begin{array}{l} 1Fe_2(Si_3O_8)_2(FeH_2O_2)_2H_2 \\ +3Fe_2(SiO_4)_2(FeH_2O_2)_2H_2 \end{array}\right.$

Epichlorite, $\left\{\begin{array}{l} 1Mg_2(SiO_4)_2H_4+1Mg_2(Si_3O_8)_2H_4 \\ +3Mg_2(SiO_4)_2(AlH_2O_2)_2 \end{array}\right.$

Strigovite, $\left\{\begin{array}{l} 3Fe_2(SiO_4)_2(AlH_2O_2)_2H+ \\ 3Fe_2(SiO_4)_2(AlH_2O_2)_2 \\ +1Fe_2(Si_3O_8)_2(AlH_2O_2)_2 \end{array}\right.$

Epiphanite, $\left\{\begin{array}{l} Mg_2(Si_3O_8)_2(AlH_2O_2)_2 \\ +3Mg_2(SiO_4)_2(AlH_2O_2)_2 \end{array}\right.$

Here we find stilpnomelane and melanolite are orthochloritic in type; epiphanite is equivalent to aphrosiderite, and the other species are intermediate like most of the leptochlorites. The analyses discussed are these:

Stilpnomelane from Antwerp, N. Y., by Brush.

Melanolite, Somerville, Mass., by H. Wurtz.

* Bulletin, U. S. Geological Survey, No. 64.

Epichlorite, from the Hartz, by Rammelsberg.
Strigovite, Striegau, by Websky.
Epiphanite, Wermland, by Igelström.
The reduced analyses are as follows:

	Stilpnomelane.		Melanolite.	
	Found.	Calc.	Found.	Calc.
SiO_2	42·85	41·80	34·25	33·46
Fe_2O_3	24·74	26·01	29·32	29·74
FeO	23·69	23·41	26·48	26·76
H_2O	8·72	8·78	9·95	10·04
	100·00	100·00	100·00	100·00

	Epichlorite.		Strigovite.	
	Found.	Calc.	Found.	Calc.
SiO_2	43·94	45·50	29·51	30·20
Al_2O_3	17·75	16·58	24·78	24·25
FeO	----	----	36·05	36·24
MgO	27·38	28·17	----	----
H_2O	10·93	9·75	9·66	9·31
	100·00	100·00	100·00	100·00

For epiphanite Igelström's analysis needs no reduction, if we calculate with a ratio of Mg : Fe :: 7 : 5.

	Found.	Calc.
SiO_2	37·10	37·66
Al_2O_3	21·13	21·34
FeO	20·00	18·83
MgO	14·03	14·64
H_2O	7·83	7·53
	100·09	100·00

The agreements are sufficiently close to establish the validity of the hypothesis upon which the calculations rest, although they are not as good in all cases as might be desired. Still, the formulæ offered bring some order out of chaos, and are therefore entitled to consideration until something better is proposed.

As between Tschermak's theory and mine, both representing the known facts fairly well, experimental research must be the final arbiter. Until experiment has given grounds for decision either theory may properly be used as a guide. Mine is offered as a possible simplification of the problem; but both may be supplanted by something more general still. Neither theory exhausts all the possibilities of the question, and neither can claim to be much more than a step forward in the series of approximations by which the truth may be at last attained.

Washington, Dec. 12, 1891.

Art. XXIV.—*Recent Fossils near Boston;* by Warren Upham.

[Read before the Boston Society of Natural History, Nov. 4, 1891.]

Fossil marine shells of the Postglacial or Recent epoch have been lately discovered at several places in the vicinity of Boston, indicating slight postglacial changes in the relative levels of land and sea, and proving considerable changes in the temperature of the sea there. These fossils have been carefully collected and studied by Miss D. L. Bryant, of the class of 1891, Massachusetts Institute of Technology; and, with topographic and geologic notes of the localities of their occurrence, they were the theme of her graduating thesis, to which I am indebted for a large share of both the observed facts and the conclusions drawn from them, as here presented. Another interesting collection has been made by Mr. Collier Cobb, of the Institute of Technology, instructor in geology and palæontology. Miss Bryant gives lists of species obtained by excavations and dredging in three localities.

1. Grading and deep trenches along the valley and estuary of Muddy River, adjoining Brookline and forming the western continuation of a new park of the city of Boston, encountered a fossiliferous clayey stratum a few feet thick, lying near the present level of low tide, underlain by stratified clay, and directly overlain by a bed of peat about one foot thick, which is succeeded by the latest fine muddy alluvium of this stream, from 5 to 12 feet in thickness. In the upper part of the clay, the thirteen species noted by asterisks in the first column of the following table were found, occurring in abundance together, except that the oysters were restricted chiefly to one place.

2. In the dredging of the Charles River during the construction of the new bridge from the Back Bay district of Boston to Cambridgeport, at a distance about one and a half miles west of the State House, there was brought up first river mud, which had a thickness of several feet, and next sand containing shells of twelve species noted in the second column of the table. The river here is a broad tidal estuary, a great part of which has been filled and now constitutes the Back Bay district; and the ground where these fossils were dredged forms part of the deepest channel of this bay or enlargement of the Charles River back of the original peninsula of Boston. The fossiliferous sand was ten feet or more below mean low

tide level, above which the mean height of the tide, both in the Charles River and in Boston Harbor, is ten feet.

The most abundant species here, occurring in great numbers and of large size, are *Mya arenaria*, *Venus mercenaria*, *Pecten irradians*, and *Ostrea Virginiana*. Some of the shells of the long clam (*Mya*) measure five inches in length and three inches in width. A small oyster shell in this bed is exceptional, the usual length being eight inches, with a width of two to three inches; while many are ten inches long, and one valve has a thickness of one and a half inches.

Table of Recent Fossils, Boston, Mass.

Species.	Muddy River.	Charles River.	City Point.	Present geographic range.
Balanus balanoides Stimpson.	*			Shores of whole North Atlantic.
Tritia trivittata Adams.	*	*	*	Fla. to G. of St. Lawrence.
Ilyanassa obsoleta Stimpson.	*	*	*	G. of Mex. to Cape Cod; local north to G. of St. Lawrence.
Urosalpinx cinerea Stimpson.	*	*	*	Same as preceding.
Purpura lapillus Lam.			*	E. end of Long Island to Arctic Ocean.
Anachis avara Perkins.		*		G. of Mex. to Mass. Bay.
Lunatia heros Adams.	*	*	*	Ga. to S. Labrador.
Crepidula fornicata Lam.			*	G. of Mex. to Mass. Bay; local north to G. of St. L.
Crepidula plana Say.			*	Same as preceding.
Littorina rudis Gould.	*			N. J. to Arctic Ocean.
Utriculus canaliculatus Stimpson.	*			S. C. to Mass. Bay.
Mya arenaria L.	*	*	*	S. C. to Arctic Ocean.
Tagelus gibbus Gray.			*	W. Indies and G. of Mex. to Cape Cod.
Macoma fragilis Adams.	*	*	*	Ga. to Greenland.
Mactra solidissima Chemnitz.			*	Texas to Labrador.
Mulinia lateralis Gray.	*	*	*	Texas to Mass. Bay.
Venus mercenaria L.	*	*	*	Fla. to Mass. Bay; local north to G. of St. L.
Lævicardium Mortoni Perkins.			*	G. of Mex. to Cape Cod; local north to N. S.
Astarte undata Gould.			*	L. I. Sound to G. of St. Lawrence.
Lucina filosa Stimpson.			*	Conn. to Maine.
Modiola plicatula Lam.	*	*	*	Ga. to Casco Bay, Maine; local north to G. of St. L.
Pecten irradians Lam.		*	*	G. of Mex. to Cape Cod; local north to N. S.
Pecten tenuicostatus Mighels.			*	N. J. to Labrador.
Anomia glabra Verrill.			*	Fla. to Cape Cod; local north to Cape Sable, N. S.
Ostrea Virginiana Lister.	*	*	*	G. of Mex. to Cape Cod; local N. to Bay of Chaleurs, G. of St. L.

3. At City Point, the east extremity of South Boston (known as Dorchester Heights in the history of the Revolution), dredging is in progress for deepening an adjacent part of the harbor, and the mud and sand thus removed are used in the extension of City Point for the site of the Marine Park. The depth of water where the dredging is being done, midway between the Point and Castle Island, is about ten feet below mean low tide, and the excavation goes several feet lower, bringing up abundant fossil shells. Twenty-one species, noted in the third column, have been identified here.

The four species mentioned for their abundance in the Charles River are also very plentiful at City Point, having similar large size, which shows that in both places they had favorable conditions for luxuriant growth. Chief among these conditions are mild temperature and clearness of the water, such as are found in estuaries and shallow bays, sheltered from the waves of storms.

Taken as a whole, the twenty-five species comprised in the identified fauna of the three localities belong in their present geographic range to a somewhat more southern and warmer portion of our coast. Fourteen are distinctly southern, and reach their northward limits at Cape Cod or in Massachusetts Bay, and in one instance near Portland, Maine; excepting that several of them occur in isolated colonies far north of their general and continuous range, as in Casco and Quahog Bays, Maine, and especially in the shallow southern part or Acadian Bay of the Gulf of St. Lawrence, from Cape Breton Island to the Bay of Chaleurs.* The occurrence of these southern mollusks, which are mostly now absent, or local and rare, north of Cape Cod, shows that the sea here during some part of the Recent epoch has been warmer than at the present time. Six of the fourteen, namely, *Iyanassa obsoleta*, *Urosalpinx cinerea*, *Mulinia lateralis*, *Venus mercenaria*, *Modiola plicatula*, and *Ostrea Virginiana*, occur in each of the three localities noted, and indicate the contemporaneousness of these deposits. All of the eleven northern species, some of which

* After the presentation of this paper before the Boston Society of Natural History, the author learned of Mr. W. F. Ganong's admirable memoir, "Southern Invertebrates on the Shores of Acadia," published a few months ago in the Transactions of the Royal Society of Canada, vol. viii, sec. iv, for 1890, pp. 167–185. Mr. Ganong gives a history of the discovery of the character of the colonies; a list of marine invertebrates belonging to the Virginian fauna, which occur upon the coasts of Acadia and Maine, with tabular reference to their known localities; and a discussion of their recent extinction on intervening portions of the coast thence south to Massachusetts Bay and Cape Cod. He accepts the explanation of Verrill and Dawson, noticed on a following page, for the present refrigeration of the sea here; but also points to the recent increasing severity of cold in Greenland and Iceland, and suggests that the marine currents there likewise have been lately warmer than now.

extend to the Arctic Ocean, but including one found only on the coast of New England, range to southward limits beyond Cape Cod. In short, the temperature of the sea in Massachusetts Bay and in the estuaries of its rivers, at the time represented by these deposits, was evidently like that of the sea now on the southern coast of New England, which, besides the increase of the sun's heat due to the lower latitude, receives some contribution from the warmth of the Gulf Stream, whereas the waters of the Gulf of Maine and Massachusetts Bay are chilled by a coastal current from the north.

The relative heights of land and sea were apparently almost the same as now. Every one of the twenty-five recorded species flourishes on the shore between the levels of high and low tide, or at the plane of extreme low tide, or in shallow water of a few fathoms. In the list of each locality are species that prefer a depth slightly below the lowest tide, and each also has other species that are chiefly restricted to the shore above low water mark. Probably the best interpretation is that suggested by the layer of peat at the first locality, immediately overlying the fossils, near the low tide level. The water there was gradually becoming shallower, and the land was finally lifted above the reach of the tide at the time of formation of the peat. Subsequently it has been depressed at least several feet, which latest movement has now apparently ceased on this part of the coast.

Postglacial oscillations of considerable amount, thus lifting the land and afterward depressing it, are known to have affected a large part of our Atlantic seaboard; and Prof. A. E. Verrill* and Sir William Dawson† believe that these recent changes of level have been sufficient to explain the important changes of temperature of the sea here, whereby southern mollusks were permitted to extend northward to the Gulf of St. Lawrence but have since been exterminated, excepting isolated colonies, north of Cape Cod and Massachusetts Bay. Both these authors are inclined to attribute the northward extension of the southern fauna to a recent time of greater elevation of our coast, which is abundantly attested to a certain amount, ranging from 10 to at least 40 feet,‡ by stumps of forests, rooted where they grew, and by peat bogs, now found submerged by the sea at many places along all the distance from New Jersey to Newfoundland. Professor Verrill

* This Journal, III, vol. vii, pp. 134–8, Feb., 1874.

† Acadian Geology, Third edition, with Supplement, 1878.

‡ According to Sir William Dawson, l. c., p. 31. Since this paper was prepared, the author finds that Mr. Robert Chalmers reports a peat bed under the Tantramar salt marsh at the head of the Bay of Fundy, about 80 feet below the present high tide level (Annual Report of the Geological and Natural History Survey of Canada, new series, vol. iv, for 1888–89, pp. 42 A and 10 N).

suggests that the Strait of Belle Isle, which is about ten miles wide and 180 feet deep in its narrowest and shallowest part, may have been closed by the elevation, shutting out the cold waters that pour through it, carrying small icebergs and floes into the Gulf of St. Lawrence; while as great an uplift of the extensive shallow Fishing Banks would ward off the arctic current far into the ocean. If we had to consider this coast alone, the explanation would seem very acceptable; but evidences of such warmer postglacial temperature, both of sea and land, succeeded now by a moderate degree of refrigeration, are found to extend over all the North Atlantic region, including also Greenland, Iceland, northwestern Europe, and even Spitzbergen.* We therefore must conclude that these climatic changes probably have depended in common on farther reaching causes and conditions, which may yet have consisted chiefly in geographic movements of elevation and subsidence, with their effect on the general oceanic circulation.

Between the time of departure of the ice-sheet, at the close of the Glacial period, and the time of northward migration of the southern marine fauna, a very important upward movement had taken place, affecting the eastern provinces of Canada and the northern two-thirds of New England, extending south to the latitude of Boston. To speak more strictly, however, this uplifting of our part of the continent was limited southeastward by a line drawn approximately from the mouth of the Hudson northeast to Boston and onward through Nova Scotia. When the ice-sheet was being withdrawn from this region, the country south of this line stood somewhat higher than now, as is shown by the channels of streams that flowed away from the melting ice and ran across the modified drift plains which form the southern shores of Long Island, Martha's Vineyard, Nantucket, and Cape Cod. A subsequent depression of the land there, continuing perhaps to the present time, has brought the sea into these old river courses. But north and northwest from this line the land at the time of recession of the ice-sheet was lower than now, and the coast and estuaries were more submerged by the sea. At Boston and northward to Cape Ann the depression appears to have been no more than 10 to 25 feet. Fossiliferous beds overlying the till show that the vertical amount of the marine submergence in the vicinity of Portsmouth was about 150 feet; along the coast of Maine, from 150 to about 300 feet; on the northwestern shore of Nova Scotia, about 40 feet; thence increasing westward to about 200 feet in the basin of the Bay of Chaleurs, 375 feet in

* James Geikie, Prehistoric Europe, chapters xx and xxi, 1881. Warren Upham, "On the Cause of the Glacial Period," Am. Geologist, vol. vi, pp. 327–339, Dec., 1890.

the St. Lawrence valley opposite the Saguenay, and 520 feet at Montreal; 300 to 400 feet, increasing from south to north, in the basin of Lake Champlain; about 275 feet at Ogdensburgh, and 450 feet near the city of Ottawa; 300 to 500 feet on the country southwest of James Bay; in Labrador increasing northward to 1,500 feet at Nachvak, according to Dr. Robert Bell; and in northern Greenland and Grinnell Land, from 1,000 to 2,000 feet. That the land northward from Boston was so much lower while the ice-sheet was being melted away, is proved by the occurrence of fossil shells of *Leda arctica* Gray, which is now found living only in Arctic seas where they receive muddy streams from existing glaciers and from the Greenland ice-sheet. This species is plentiful in the stratified clays resting on the till in the St. Lawrence valley, in New Brunswick, and Maine, extending south to Portsmouth, N. H. But it is known that the land was elevated from this depression to about its present height before the sea here became warm and the southern mollusks migrated along this coast to the Gulf of St. Lawrence; for in the extensive lists of the fossil fauna of these beds none of the southern species is included, excepting perhaps the oyster in southwestern Maine.*

From the Champlain submergence attending the departure of the ice, the land was raised somewhat higher than now, and its latest movement from New Jersey to southern Greenland has been a moderate depression. The vertical amount of this recent subsidence is undetermined, beyond that known by stumps and peat now covered by the sea; and it is difficult to estimate how far this recent and probably slight oscillation may have tended to produce formerly warmer and now cold sea currents, with the faunal migration that is represented by the marine colonies of southern species. It seems unlikely, however, as before remarked, that the warmer marine temperature was due to local conditions of our coast, since it prevailed throughout all the North Atlantic Ocean. The fossils of the Champlain beds of our northeastern shores and also of northwestern Europe show a gradual change from an Arctic and glacial climate at the maximum of the depression to a cool temperate climate, nearly the same as now, before the re-elevation brought the land up to its present height. After this level was generally attained or somewhat surpassed, the southern warmer temperate species spread northward along both sides of the Atlantic to boreal and even Arctic regions, where

* C. H. Hitchcock, "The Geology of Portland," Proc. A. A. A. S., vol. xxii, for 1873, pp. 163–175. A. S. Packard. "Observations on the Glacial Phenomena of Labrador and Maine," Memoirs of the Boston Society of Natural History, vol. i, 1865, pp. 210–262. J. W. Dawson. Notes on the Post-pliocene Geology of Canada, 1872, pp. 112 (from the Canadian Naturalist, new series, vol. vi).

they are no longer able to live excepting in isolated colonies that are preserved here and there in sheltered shallow bays.

Looking for causes of these changes of temperature in the North Atlantic and the adjoining countries, it seems to me very probable that they were due mainly to a formerly larger volume of the warm oceanic current which is named the Gulf Stream because a considerable part of it issues from the Gulf of Mexico, flowing through the Strait of Florida, while perhaps a larger part leaves the tropics east of Cuba and the Bahamas. This very broad current pours northward to the Arctic regions and there enters an otherwise almost completely enclosed ocean, from which counter currents nearly at the temperature of melting ice flow back along the Labrador coast and in the depths of the Atlantic under its warmer surface. But within the Recent epoch, during which these climatal changes have taken place, an elevation of a large region of Alaska and eastern Siberia has been in progress, slowly diminishing the depth and width of Bering Strait.* The recency of this uplifting, probably still going on, is shown, like that of the basin of Hudson Bay, by drift-wood on the sea shores, lying far above the level now reached by storm waves at the highest tides. Mr. Dall reports that the current of the shallow Bering Strait, which has a maximum depth of only 180 feet and is about 36 miles wide, passes north into the Arctic Ocean ;† but it may have been reversed when the strait was formerly much larger, being thus an outlet for a part of the waters carried north by the Gulf Stream. The North Atlantic and the Arctic Ocean could then have received more of its northward warm current, giving a milder climate to northeastern North America and northwestern Europe and adjacent Arctic lands. On the other hand, an outflow from the polar sea through Bering Strait would be a frigid current, carrying greater cold to Alaska, British Columbia, and the Pacific coast of the United States.

So nicely balanced are the conditions on which variations of climate depend, that the former depression of Bering Strait, through resulting changes in the oceanic circulation, may have been a very important element, re-enforced probably by contemporaneous greater elevation of the Cordilleran mountain belt from the St. Elias range to the Sierra Nevada, in causing these mountains and the adjoining lower ground to bear very lately, as Russell and Becker have shown, extensive glaciers or even ice-sheets, which have now disappeared from the south-

* William H. Dall, Alaska and its Resources, 1870, pp. 462-466.
† Ibid., p. 285.

ern part of this belt and are fast retreating in Alaska.* The last 500 or 1,000 years, according to Russell, have been marked by rapid glacial recession in the St. Elias region. But during the same or a longer time the North Atlantic area has been growing colder, gradually excluding the southern mollusks, causing the ice-sheet of Greenland to increase again, and giving to that country a much less hospitable climate than during the prosperous period of the Norse colonies, from 900 to 500 years ago. Both the decrease of the Alaskan glaciers and the increase of cold and of ice accumulation in Greenland are attributable, as I believe, to the present partial closure of the passage between the Arctic and Pacific Oceans.

In another way, however, which is perhaps more probable, that is, by assuming that the principal current through the formerly enlarged Bering Strait flowed as now northward, we may almost equally well explain the climatic changes of both the western Cordilleran belt and the North Atlantic area. Such increased northward outflow from the Pacific would be subtracted from the warm Kuro Siwo or Japan current, the greater part of which passes to the east and south along the shores of Alaska, British Columbia, and the Pacific States, and would thus tend to produce the cold of the recent Cordilleran glaciation. The formerly large branch of the Japan current entering the Arctic Ocean by Bering Strait would be partly, and probably almost wholly, carried thence eastward along the northern coast of North America and through its archipelago to Baffin Bay, Davis Strait, and the North Atlantic, bringing somewhat milder climatic conditions to Greenland and to all those shores where the colonies of southern marine mollusks are known. With the subsequent decrease of the size of Bering Strait, during the past 1,000 years, sending more of the Japan current to our Pacific coast, the Cordilleran and Alaskan glaciers would be melted away or greatly reduced, as to-day, but Greenland and the North Atlantic area would become colder, as seems to be well proved within the present historic period.

To the same very late date we must assign the extinction of the southern molluscan species on the eastern coast of New England and the southern coast of New Brunswick and Nova Scotia. During the time of accumulation of the aboriginal shell-heaps or kjökken-möddings of Maine, and even within the

*I. C. Russell, Geological History of Lake Lahontan, U. S. Geol. Survey, Monograph xi, 1885, p. 273; Bulletin, G. S. A., vol. i, 1890, p. 142; Expedition to Mount St. Elias, Alaska, National Geographic Magazine, vol. iii, 1891, pp. 64, 93, 98, 100, 104, 112, 173. G. F. Becker, Bulletin, G. S. A., vol. ii, 1891, p. 196. Warren Upham, this Journal, III, vol. xli, pp. 41, 51, Jan., 1891; Am. Geologist, vol. viii, p. 150, Sept., 1891.

270 years since the first settlement in Massachusetts, very significant restriction and extinction can be shown. For example, Professor Verrill states that dredging reveals the occurrence of great beds of oyster shells a few feet beneath the harbor mud at Portland, where they are associated with the quahog (*Venus mercenaria*), scallop (*Pecten irradians*), and other southern species; and that the oysters and scallops "had apparently become extinct in the vicinity of Portland Harbor before the period of the Indian shell-heaps, for neither of these species occurs in the heaps on the adjacent islands, while the quahogs lingered on until that time, but have subsequently died out everywhere in this region, except at Quahog Bay."* Still later and more surprising is the extinction of the oyster from many localities on the coast of Maine and eastern Massachusetts.† Native oyster banks in the Charles and Mystic Rivers two hundred years ago were so productive that an enumeration of the exports from Boston to the West Indies and Spain in 1687 included "oysters salted in barrels, great quantities of which are taken here." Now there probably remain, according to Ingersoll, only two localities on the New England coast north of Cape Cod, where native oysters survive, these being Great Bay in New Hampshire, back of Portsmouth, and the Sheepscot River in Maine. They are likewise almost wholly wanting on the Canadian continuation of the coast until Cape Breton Island is reached; but thence westward in the Gulf of St. Lawrence they are plentiful, with numerous other southern species, to the Bay of Chaleurs. The extinction of oysters, and of their southern associates, has been rapidly going on from Nova Scotia to Cape Cod since the earliest settlement of the country, due probably not so much to their exhaustion by being gathered for food, or to any and all other causes, as to a progressive refrigeration of the sea; and this seems referable, as before indicated, to changes in the volume and warmth of marine currents, which changes ultimately may have been caused by the former depression and present uplifting of the region of Bering Strait.

* This Journal, III, vol. vii, p. 137.

† Ernest Ingersoll, Report on the Oyster-Industry of the United States, Tenth Census, 1881.

Art. XXV.—*The Highest Old Shore Line on Mackinac Island;** by F. B. Taylor.

Evidence of post-glacial submergence has long been known to exist on Mackinac Island, which lies in the strait between Lake Huron and Lake Michigan. Its amount has been variously stated by different writers, some putting it at 250 feet, while others claim that evidences on the higher parts of the adjacent mainland indicate an amount of submergence that would rise far above the summit of the island which attains an altitude of about 300 feet above the present level of Lake Huron. The observations of which I give an account here were made during the autumns of 1890 and 1891.

With the exception of the rocky faces of the great limestone cliffs which rise on its eastern and western sides, all the lower levels of Mackinac Island show plain evidence of post-glacial submergence. The modern beach is composed almost entirely of limestone pebbles which are generally well rounded. The proportion of crystalline drift material from the north is not great and is confined mainly to bowlders of considerable size. The narrow strip of land upon which the village is built, and which rises to an altitude of 40 to 50 feet at the base of the cliff, is composed entirely of the same characteristic beach material; as may be seen in any of the little gardens of the villagers and in the deep cut back of the Astor House and the old court house. But on ascending to the higher levels of the island the evidences of post-glacial submergence are even more marked. At an altitude of about 170 feet there is a heavy, well developed beach ridge. This ridge is the lowest of a series of four or five like ridges which rise by successive steps to an altitude of about 205 feet above the strait or about 787 feet above sea level. These old beaches may be seen to best advantage on the short target range back of Fort Mackinac. The ground is there cleared of trees and is covered with a short, thick turf, so that the whole series of beach ridges, with their intervening troughs and minor ridges, is admirably exposed to view. At this place the ridges are parallel and comparatively narrow, though strongly developed, and they are also more compactly arranged and more convenient of access than in any other part of the island.

The short target range crosses the beaches nearly at right angles and the width of the series is here a little less than a quarter of a mile. But on the southwestern side of the island

* An abstract of this paper was read before the Geological Section of the A. A. A. S., at Washington.

it is three times this width. In some places two or more ridges run together and form one, as is often observed elsewhere. On the short range four heavy ridges are clearly seen with possibly a fifth less distinctly formed. In two of the wider troughs, which are five to six feet deep between the main ridges, there are apparently several other little ridges, one to two feet in height. A road which runs parallel to the range and close to its west side cuts the top of each ridge and shows its composition to be a characteristic beach formation. The 205 foot beach is not only the highest one of the series here described, but also the highest on the island. If this ridge be followed through its full extent around the higher ground, it will be found to surround a small tract on three sides. On the remaining side, which is a long, straight line of limestone cliffs facing towards the northeast, all the beach ridges, except the lowest or 170 foot ridge, are wanting. This beach is situated at a considerable distance from the cliff, and the ground between is a broad, level plain with an altitude of 170 to 175 feet. On this plain a heavy talus of fragments and angular limestone bowlders lies against the base of the cliff. While the waves were forming the 205 foot beach around the other sides of the circumscribed tract, they were beating against this northeast cliff and the water on the plain at its base was 30 to 35 feet deep.

The little island of ancient times, thus defined, was about three-fourths of a mile long and less than half as wide, with its longer axis running about northwest and southeast. Its north end was a sharp promontory formed by the long cliff facing northeast, as just described, and another shorter one facing almost directly west. At the base of the latter the 205 foot beach is well developed, but it is very narrow and the ground drops off rapidly westward to the 170 foot plain. The highest point of the ancient island is at its southern end which forms a rounded promontory and rises to a little less than 100 feet above the 205 foot beach. This point is now crowned by the earthworks of old Fort Holmes, built in 1812, and the descent to the 170 foot plain on the east, and to the 205 foot beach on the south is a steep slope of drift. On its west side, and about a quarter of a mile south of its north point, the surface of the island descends gradually to the 205 foot level. The upper beach is here wide and flat and encloses a considerable tract of low ground behind it.

All of my measurements of altitude were made with an aneroid barometer and are subject to the inaccuracy of that instrument. But the 170 and 205 foot beach levels represent in each case the mean of more than a dozen independent observations taken under favorable conditions and are therefore

probably not far from true. But after determining the fact that the highest old shore line on Mackinac Island has an altitude of about 205 feet above Lake Huron, another broader and more difficult question arose. Did post-glacial submergence exceed this amount? Suppose that it did, as has been implied and suggested by those who point to shore lines at higher levels on the adjacent mainland. What evidence can be brought to bear upon this question?

A careful examination of the ancient little island of Mackinac, as described above, and of the surrounding mainland reveals among others, the following facts: The whole surface of the ancient island, except where the rocks were laid bare along the edges by the formation of cliffs, is covered with glacial drift. This drift is typical in its composition and topographical features. Its surface has that irregular rolling appearance which is characteristic of a drift-covered, broken country. Along the edges near the cliffs the drift has been notched by the little rain rills which carry away the surface water. Otherwise, the surface shows no evidence of post-glacial modification.

The composition of the drift is well shown in the excavations of old Fort Holmes on the highest point of the island. The parapet of the fort was built of material dug partly out of the interior of the enclosure and partly out of an outer ditch. This ditch is five or six feet deep and seems to have been excavated entirely out of bowlder clay, which is well exposed in several foot paths which cross the earthworks. The clay is very tough and of a reddish color, and when wet is quite slippery under foot. But when it is dried in the sun, it forms a very hard surface. It contains a fair sprinkling of bowlders of moderate size, but appears at the fort to include comparatively little sand and gravel. The clay and coarser constituents form a heterogeneous mixture in characteristic drift fashion, and a fair proportion of the bowlders show striæ. Although the composition of the drift varies somewhat in different places, it everywhere presents such characters as clearly preclude the supposition that it has been washed or worked over by the action of waves since its deposition by the ice sheet.

The whole surface of the ancient island is well sprinkled with bowlders and a large number of them are erratics of northern origin. With hardly an exception their exposed surfaces are strongly weathered. I found only two small surface bowlders with striæ still preserved, and both looked so fresh that they probably came from some of the excavations near by. I examined hundreds of bowlders below the 205 foot level, but found none with glacial scratches. Exposures in

road-cuts and gravel-pits are common on all parts of the island, but I found not a single striated pebble in any of those below the 205 foot level. Below this level the loose material of the island generally appears to be rounded and water-worn. The sharp angular fragments which are intermingled in small quantities are of the country rock and were probably freshly derived from the cliffs. I found nothing resembling bowlder clay below the 205 foot level, though it probably occurs in protected places.

During the last season a pit was dug at the target on the short range which is against the foot of Fort Holmes hill, and an excavation was also made at a higher level to obtain material for filling in behind a log backstop. The pit is in the trough behind the 205 foot beach, and the backstop is about ten feet higher on the side of the hill. A number of beautifully striated pebbles were found which had been thrown out of the pit. Almost the whole mass of material excavated for the backstop consisted of Paleolithic flint chips originally derived, apparently, from the chert nodules of the limestone of the upper cliffs. This excavation was about four feet deep.

Altogether, the appearance of the surface of Mackinac Island seems to show that all parts of its surface, up to the level of 205 feet, has been modified by wave action since the deposition of the glacial drift; but that above that level no such modification has taken place.

An examination of the mainland north and south of the island shows that they, too, have been post-glacially submerged up to certain levels. Within a radius of 20 miles no land reaches an altitude of more than 160 to 170 feet. McGulpin's Point on the south side of the strait, with an altitude of about 110 feet, was completely submerged. So also was the high ground on the north side near Pointe La Barbe, altitude about 140 feet, and at Gros Cap farther west and a little higher. On the shores of Little Traverse Bay, about 40 miles southwest, a heavy shore line is found near Petoskey at an altitude of about 100 feet above the lake, and a little higher at Harbor Springs on the north side of the bay. At the latter place the shore line appears as a great terrace, and from the head of the bay it is developed westward and northward continuously for a distance of more than 20 miles to a point northeast of Cross Village. At a very early day this terrace was largely cleared by the red men and is said to have been almost one continuous village for its whole length.

At the time of the great post-glacial submergence the high tract north of Little Traverse Bay and west of the G. R. and I. Ry. was a large island, nearly round and about 15 miles in diameter. On the south side of the bay the shore line ex-

tends inland eastward from Petoskey at least 20 miles, and passes south of Crooked, Pickerel, Burt and Mullet Lakes. Beyond this its place is not yet determined. Southwest from Petoskey the old shore line is quite irregular but continuous, at least as far as Traverse City, a distance of about 50 miles, at which point the old delta of the Boardman River shows the water level to have been at an altitude of about 80 feet.

The identity of this great deserted shore line with that found on the shores of Lake Huron and Georgian Bay, called by Professor J. W. Spencer, the Algonquin beach, and described by him in recent numbers of this Journal, seems almost certain. The upper beaches of Mackinac Island are without doubt only an isolated part of the same great shore line.

It is well known that almost the whole of the northern peninsula of Michigan has been submerged since the glacial epoch. This area of submergence is continuous with that which I have described on the south side of Mackinac Strait, and includes a large part of the south shore of Lake Superior. Some years ago I saw deserted shore lines near Au Train, at Marquette and at the west end of Lake Superior which probably belong to some stage of the same epoch of submergence.

The old shore line between Traverse City and Mackinac Island shows the same northward rise as has been found in post-glacial shore lines elsewhere. From Petoskey to Mackinac Island the northward component of distance is about 33 miles and the Mackinac beach is about 100 feet higher than that at Petoskey. The northward component of differential elevation between these points is, therefore, three feet per mile. From Traverse City to Petoskey the northward component of distance is about 41 miles, and the difference of elevation of the beaches is approximately 20 feet, making the northward factor of differential elevation six inches per mile. Two isolated observations near Levering and Pellston 15 miles north of Petoskey on the G. R. and I. Ry. seem to show an elevation for the shore lines at those places of not less than 150 or 160 feet. This is somewhat higher than the plane directly connecting Petoskey and Mackinac Island. But the local variation of differential elevation which seems to be suggested by these two observations needs further verification.

Near Harbor Springs and Wequetonsing on the north side of Little Traverse Bay, and at Petoskey and Traverse City, the evidence that post-glacial submergence has not extended above the level of the observed old shore line is fully as plain as on the island of Mackinac. This statement applies to the surface forms and the composition of the drift, and also to the presence of striated bowlders in the drift above the line and their absence below it. Back of Petoskey the hills rise 300

feet or more above the lake. They have been cleared for cultivation and they show those peculiarities of surface formation which characterize only an unmodified drift topography. They are heavily drifted and their surfaces have those long, graceful curves with upward convexities which are unerringly attributed to the constructive action of the ice sheet, and which are plainly not a product of any known destructive or eroding agent. In case of greater submergence they would be exposed, as the shore below is to-day, to the full force of the west and northwest winds, and they could hardly escape the eroding action of the waves. The modified course of Bear Creek proves that during the formation of the Algonquin beach at this point, and during the entire subsequent recession of the waters down to their present level, the waves of the west winds have played a strongly predominant part in the modification of the shore. Below the Standard Oil Co.'s station south of Petoskey, Bear Creek runs towards the northwest and once entered the lake in that direction through a narrow gorge. But its present course turns abruptly from northwest to northeast where its banks are about 90 to 100 feet above the lake. From this point it flows about half a mile to its mouth in a course nearly parallel with the present shore, and descends quite rapidly. There are good exposures in the banks at the bend and they show deep sections of characteristic beach material—rounded pebbles, gravel and sand—up to about 90 feet elevation. The position of this material shows that at the time of the Algonquin submergence the eastward littoral transportation was so great that it forced the stream to turn aside in the direction of the movement, and the continuation of the stream in the same modified course ever since shows that the same disturbing element has acted continuously at lower levels. The shortness of the rock gorge below the bend indicates a comparatively recent date for the change. Many lakes along this shore have been partly formed by littoral dams of Algonquin or later age.

But in respect to exposure to wave action, Mackinac Island seems to me to be a test case. For its geographical position is such that in the event of a general submergence of that region to or beyond the depth indicated by the Algonquin beach, it would stand alone in a wide expanse of water. The nearest mainland would then be about 30 miles to the south and the nearest islands about 20 miles to the north and southwest. In all other directions open water would stretch away 100 to 200 miles. From Traverse City to Mackinac Island and at least 25 miles farther north, the plane of wave erosion appears to have acted at every horizon up to the level of the Algonquin beach. But above that plane there is no evidence of such action; at

least up to a level of 100 feet above the Algonquin beach as seen on Mackinac Island, and 200 feet above it as seen at Petoskey.

It might be supposed that the small area of Mackinac Island was submerged and re-elevated by movements so sudden that the waves had no time for effective action at any horizon between 205 and 300 feet. But the difficulties in the way of such a supposition are many and great, and when it becomes necessary to extend the application of it to an area 100 miles long and even to the whole area of the three upper Great Lakes, the difficulties become insuperable.

The most impressive feature of the old shore line which I have described is the great strength of its development. The time during which the water level stood at or within 35 feet of its highest stage must have been of very long duration, for by far the strongest development is within this limit. The appearance is just such as would be produced if the water had risen slowly at a steadily decreasing rate, stood long at its highest level, and then had fallen away again as slowly and at a steadily increasing rate. The Iroquois beach of the Ontario basin, described by Dr. G. K. Gilbert and Professor J. W. Spencer, has the same strong development, except where lack of drift gave little loose material for the waves to work upon.

If the rise of the Algonquin beach on the east side of the Georgian Bay continues northward, it must extend far above the pass at Lake Nipissing. The Iroquois beach has the same northward rise, and if its approximate mean plane, not counting the exceptional high grade northeast of Watertown, N. Y., be produced northward, it too strikes much higher than the Nipissing pass. The two planes come as near together at Nipissing as could be expected in view of the considerable extend of irregular, local earth-warping. Considering this fact and the general similarity of the two beaches, it seems probable that the Iroquois and Algonquin beaches are in reality one continuous line. Terraces have been noted on the hills at Nipissing, at an altitude of several hundred feet above the pass and they are in all probability a part of the connecting link.

The generally accepted explanation of the origin of all the old shore lines of the basins of the Great Lakes is that they were made by bodies of water held as lakes in front of the ice sheet as it retreated northward. But this theory does not seem applicable to the Algonquin and Iroquois beaches. The long duration of wave action at one horizon, as attested by the strong development of these lines, is hardly reconcilable with the idea of an ice dam, which must have been formed by an

ice sheet which we know to have retreated with a halting, fluctuating movement.

But there is positive evidence of marine post-glacial submergence in the St. Lawrence valley. On the mountain at Montreal marine shell beds occur at an altitude of 520 feet above the sea, and in the Pleistocene deposits of Vermont near Lake Champlain the skeleton of a whale was found. In the depths of Lake Superior a marine or brackish water organism is found living to-day. These facts are all well known and their *prima facie* significance is unmistakable. Yet many geologists put them aside for the ice-dam theory which seems more complete. The idea of the ice dam accounts for the submergence which made the shore lines. But the facts proving marine submergence do not explain the cause of that submergence. There is no proof that the waves which washed the Iroquois beach were of fresh water. They may have been salt, but more probably were brackish. If there were no evidence of marine post-glacial submergence in the St. Lawrence valley, then, on purely negative evidence, we might remain in reasonable doubt. But the marine shells at Montreal and the Champlain whale are positive evidence of marine submergence of those localities, and they are not more than 150 miles from the Iroquois beach at Watertown, N. Y., and 100 miles from its position at Fine. No adequate reason can be given why we may not make the almost obvious inference that these marine beds are in the same area of post-glacial submergence as the Iroquois beach. We know that salt water stood more than 520 feet deep at Montreal, and we do *not* know that the Iroquois waves were of fresh water. It seems more pertinent, therefore, to ask what barrier could have held the salt water out of the Ontario basin, than what could have held a supposable body of fresh water in.

Higher shore lines exist in the Ontario and Erie basins, but they are generally comparatively weak in development and many of them are known to be of a distinctly fragmentary character, suggesting isolated areas of submergence and less duration of time in their formation. All those which have been thoroughly identified as shore lines are in hydrographic basins so situated with respect to the several lobes of the retreating ice sheet and certain old disused river beds as to strongly suggest the operation of ice dams. The longest beaches yet found at the higher levels are those of the Erie basin. The Maumee beach, which is the highest, extends eastward from Fort Wayne and ends at Cleveland, and Dr. Gilbert found the termini of others of the same series in western New York. All these termini are in comparatively open

country where the lines could easily be followed farther if they existed. No such end has ever been found for the Algonquin or Iroquois beaches. They have merely been lost in the bush, or rocky, scantily drifted regions, and await more careful and energetic exploration.

If shore lines are found in the highlands 50 to 70 miles south of Mackinac Island, as has been reported, they must have been formed by ice-dammed lakes which were drained off and had disappeared before the summit of the island itself emerged from the ice. The higher beaches of the Ontario basin and all those of the Erie basin were probably made by ice-dammed lakes. But the heavily developed and apparently continuous Algonquin and Iroquois beaches, including the 170–205 foot beaches of Mackinac Island,—probably all one line,—were made by waters which had open connection through a broad strait at Nipissing with the Gulf of St. Lawrence, and the Atlantic Ocean. The facts suggest a provisional classification of the deserted beaches of the Great Lakes into two divisions, produced by entirely different causes, and probably at widely separated times, namely: the higher level, fragmentary and comparatively weak beaches, probably produced by ice-dammed lakes, and the lower, strongly developed, continuous beaches of marine origin, formed, probably, long after the ice sheet had disappeared from eastern North America.

Fort Wayne, Ind., Nov. 18, 1891.

Art. XXVI.—*On the Nature of Colloid Solutions;* by C. E. Linebarger.

It seems to be the general opinion among scientists that the solutions of colloid substances, such as albumen, silicic acid, tungstic acid, etc., differ in their nature from solutions of crystalloid substances. The great difference in the velocity of diffusion of solutions of crystalloids on the one hand and of colloids on the other, together with the fact that certain animal membranes and parchment paper are impermeable for colloids, but allow crystalloids to pass freely through their pores, led Graham* to invent the names *crystalloid* and *colloid*, thus dividing substances into two great classes. Graham in his paper states distinctly the differences existing between crystalloids and colloids and ventures the question whether the basis of the colloid state may not be in the complex

* Liebig's Ann., cxxi, 1, 1862.

character of the molecule. However, the facts that the solutions of colloid substances do not have an appreciably higher boiling point than water nor a lower freezing point, and that, in dissolving a colloid, no change of temperature takes place, or, at least, but a very slight change, seems to indicate that a colloid solution is not a solution in the ordinary sense of the term, but rather a mechanical mixture, an emulsion, the colloid being held in a state of suspension in the water.

In the last few years, able investigators have occupied themselves with the subject, and their conclusion has pretty generally been that a colloid solution is really only an emulsion, i.e., a suspension of the finely-divided colloid in the solvent. Most of the experiments have been carried out with solutions of colloid silver. But silver has the property of assuming so many allotropic forms, as shown by the researches of Carey Lea, that it is hardly justifiable to apply the deductions drawn from the phenomena exhibited by it to other colloid substances. Muthmann* describes two experiments which to his mind are convincing proof that colloid silver forms a "suspension" or emulsion with water and not a true solution.

If a solution of colloid silver be mixed with a solution of gum arabic, by adding alcohol, both silver and gum arabic are precipitated, although alcohol does not precipitate a solution of colloid silver alone. According to Muthmann, the explanation of the phenomenon is that the finely-divided silver held in suspension is dragged down by the gum arabic when alcohol is added. But Carey Lea states that a solution of litmus in water, which every one admits to be a true solution, mixed with a solution of gum arabic is also precipitated by alcohol. Muthmann's experiment can then hardly be said to prove the existence of colloid solutions differing from crystalloid solutions in that particular.

In the second experiment, Muthmann let a solution of colloid silver freeze. After melting, the originally red color of the solution had changed to a black, and it was possible by means of a good microscope to distinguish small particles of silver so finely divided, however, that after standing for a week but a portion settled down. Yet this experiment does not prove that the colloid silver is held in suspension in the water. It only shows that, by freezing, the silver is made to pass into a state of greater molecular aggregation, so that the "tagmas"† formed are visible under the microscope. I have frozen solid a solution of colloid tungstic acid, without that the properties of the solution were in the least changed. At any rate, colloid

* Ber. der d. chem. Gesellschaft, xx, 983, 1887.

† By "tagma" is understood a combination of molecules, i. e., a molecule made up of several other molecules. See Pfeffer's "Osmotische Untersuchungen," p. 32.

silver is so anomalous in its behavior that the results of experiments carried out with it cannot be well applied to other colloid substances.

Exner* has made an examination of finely-divided bodies suspended in a liquid with a view to explaining the phenomena of the Brownian movements. He prepared emulsions of gamboge by adding water to a solution of gamboge in alcohol. In this way so fine an emulsion was obtained that under ordinary conditions it kept as such indefinitely. Exner found that, if a little of this "suspension" be put in a vessel and water carefully run down over it so as to form a distinct surface of separation between the two liquids, after some days this surface separating the liquids became obliterated, in other words, diffusion took place. Accordingly, finely-divided particles held in suspension in a liquid would seem to have the power of doing work against gravity; for it is only by the expenditure of energy that a particle would pass from a lower to a higher position in the liquid. But Exner found again that, if the experiment be conducted in a room of constant temperature, after three days not only no particles had passed from the lower liquid to the upper, but that, on the contrary, a portion of the gamboge had settled down as a deposit at the bottom of the vessel. The diffusion phenomena observed in the first experiment must then have been due to changes of temperature and jarring. According to the second experiment, emulsions do not possess the property of diffusion; they are only subject to the action of gravity. Muthmann's second experiment also affords additional proof for this conclusion. But solutions of colloids diffuse, as has been shown by Graham in the case of albumin, etc. Here is then a fundamental distinction between a true solution and an emulsion. Diffusion, as has been shown by Nernst,† is due to osmotic pressure. Therefore, we would expect that a solution that diffused, would have an osmotic pressure. Pfeffer, in the course of his researches on osmosis‡ has found the osmotic pressure of a 1 per cent solution of gum arabic to be $7{\cdot}1^{cm}$ of mercury at 15°. This is the only determination of the osmotic pressure of a colloid that I know to have been made. Gum arabic, from a chemical standpoint of view, is hardly suited for an investigation of this character. Too little is known of the constitution of its molecule, and it is not always a chemical unity. What is wanted for an investigation of the osmotic pressure of colloids is a colloid as simple and stable as possible. The colloid modifications of tungstic and molybdic acids fulfill these conditions very well. A solution of colloid tungstic acid

* Wiener Ber. † Zeitschr. f. phys. Ch., ii, 613, 1888.
‡ Osmotische Untersuchungen, Leipzig, 1877.

may be frozen or heated to 150° without alteration. I have therefore made some determinations of the osmotic pressure of solutions of colloid tungstic acid in the hope of obtaining results that may throw some light upon the nature of colloid substances in solution. As osmotic pressure affords a precious means, according to the theory of van't Hoff on dilute solutions, of determining molecular mass, the results should have some interest.

The apparatus used consisted simply of a tube about 8^{cm} long and 15^{mm} in diameter; one end was well-rounded off in the flame and the other drawn out so as to form a neck. The manometer was a capillary tube with a bore of about $0{\cdot}5^{mm}$, passing loosely into the neck of the osmometer. A bit of rubber tubing is used instead of a cork. The manometer should be so adjusted that it may be pushed to and fro in the osmometer. This is accomplished by greasing well the interior of the rubber tubing. By pushing the manometer into the osmometer or by drawing it out, the pressure may be increased or decreased at pleasure. The membrane used was thick parchment paper, which was bound over the wide end of the tube by means of silk thread, perfect contact between the paper and the glass being effected by the use of a solution of good sealing wax in alcohol. A hermetic joint may thus be obtained. Of course, a great degree of accuracy cannot be obtained with an apparatus of the above description, especially when it treats of measuring high pressures. Still with pressures not exceeding 30–40^{cm} of mercury quite good measurements can be made. I have modified the apparatus somewhat, so that it is capable of much greater precision. The results obtained with the second apparatus will be published in a succeeding paper.

The osmometer is filled with the solution, the osmotic pressure of which is to be determined and the manometer inserted in the neck, care being taken that no bubbles of air be present. The osmometer is then suspended vertically in a jar filled with pure water.

Two solutions of colloid tungstic acid were prepared, which I will designate by the Roman numerals I and II.

1 c. c. of sol. I contained ·02467 grms. $(H_2WO_4)_n$
1 c. c. of sol. II contained ·0100 grms. $(H_2WO_4)_n$

The solution of tungstic acid was prepared by adding to a 5 per cent solution of sodium tungstate just enough hydrochloric acid to take up the sodium. The whole was dialyzed until no trace of salt could be detected in the outer liquid.

I filled an osmometer with sol. I, adjusted the manometer so that the pressure was about 20^{cm} of the solution, as I did not employ mercury in the manometer in this experiment, and suspended the apparatus in pure water. The solution mounted

steadily in the manometric tube and in four days had reached the height of about three yards. Having thus got an idea of what osmotic pressure the solution would exert, I repeated the experiment, using mercury* in the manometer. I pushed in the manometer so that the mercury stood at about 40^{cm}. In twenty-four hours, it had fallen to $25{\cdot}3^{cm}$, and remained at this height for about four days. It then fell slowly and in three weeks had fallen nearly 6^{cm}. In another experiment I "set" the osmometer at about 15^{cm}, and in a day or so found that the mercury had risen to $25{\cdot}1^{cm}$. Taking the mean, a solution of colloid tungstic acid containing 24·67 grms. to the liter, exerts an osmotic pressure of $25{\cdot}2^{cm}$ of mercury. The temperature at the time of the readings was 17°. Applying the formula for dilute solutions, $pv = RT$, I have $T = 290°$. $R = 84500$, and, if the molecular mass of colloid tungstic acid be 250, i. e., H_2WO_4, $v = 10377$, $p = 2317{\cdot}6^{grm}$ per cm^3 or $170{\cdot}5^{cm}$ of mercury. But the experiment gave only an osmotic pressure of $25{\cdot}2^{cm}$ of mercury, which is 6·77 times less than the theoretical. Hence, as molecular mass varies inversely as the osmotic pressure, the molecular mass of $(H_2WO_4)_n$ must be about 1693· and n nearly equal to 7.

With sol. II, I obtained as a mean of several determinations an osmotic pressure of 140^{grm} per cm^3. As the pressure with this solution was so feeble I used the solution itself in the manometer, reckoning it as water. This pressure corresponds to a molecular mass of 1718, which corresponds closely with that obtained with sol. I.

In round numbers then the molecular mass of colloidal tungstic acid is about 1700 or nearly seven times 250, and the colloidal molecule consists of seven simple molecules.

All of the phenomena exhibited by colloids may be easily explained on the assumption that the colloid molecule is very large. A solution of a colloid does not seem to lower the freezing point nor raise the boiling point because the molecular mass is so great that it has but little influence. The raising of the boiling point and lowering of the freezing point is a function of molecular mass; the larger the molecule, the less marked these properties of solutions. Colloid solutions do not differ essentially from crystalloid solutions in this particular; and the apparent difference is but one of degree. Colloid solutions lower the freezing point and raise the boiling point only a very little. A 5 per cent solution of colloidal tungstic acid, for instance, would not depress the freezing point more than 0·05°, a depression which could not be accurately measured. I determined the freezing point of sol. I, finding

* Tungstic acid attacks mercury so that at the surface of contact a blue zone forms, which gradually spreads. Yet, I do not think that it had any influence upon the osmotic pressure.

it to be 0·1°, which corresponds to a molecular mass of 456, a number upon which no weight can be laid, as doubtless most of the depression was due to the salt present in the solution.* The presence of a small amount of salt would have no effect, however, upon the osmotic pressure, since the salt could pass freely through the membrane. Osmotic pressure is then due to the colloid alone. The delicacy of the osmotic pressure method is very great. Using the solution itself to measure the pressure, a molecule 2000 times heavier than hydrogen in 1 per cent solution would support a column more than a yard high.

A colloid solution might be regarded as a step between a true solution and a true emulsion. The colloid molecule is so much larger than the water molecule that it stands to reason that the properties of colloid solutions must differ markedly from solutions of substances which possess a molecule but several times heavier than water. Hence diffusion of colloids takes place slowly; the osmotic pressure is small; and but a slight lowering of the freezing point and raising of the boiling point occurs.

As to the nature of this large molecule and how the simple molecules are combined to form the complex molecules, it is hard to give an opinion. The ease with which colloidal substances are coagulated, i. e., pass into the solid state, indicates that there exist in the solution molecular groupings similar to those existing in a solid. It is generally admitted that in solids the simple molecules unite to form more complex molecules or "tagmas." Similar "tagmas" might exist as such in the solution.

The facts are that solutions of colloids have a definite rate of diffusion and exert a definite osmotic pressure. As osmotic pressure, diffusion, lowering of the freezing point and raising of the boiling point are intimately related, we can say that colloid solutions also have freezing and boiling points differing from those of the solvent. We conclude then that a colloid solution is a solution in the ordinary acceptation of the term and not a "suspension."

I am occupied in making determinations of the osmotic pressure of colloid substances, especially of the albuminoids. Certain albuminoids, as is well known, are insoluble in pure water, but quite soluble in a solution containing a little of some salt. As this salt does not affect the osmotic pressure in the least, its presence does no harm. Thus I hope to get more of an insight into the nature of the complex substances of animal origin.

Clark University, Worcester, Mass.

*I might have determined the amount of salt present and thus easily found what depression was due to the acid alone; but as the depression was so small and the solution so dilute, the results would have been worthless.

ART. XXVII.—*Observations upon the Structural Relations of the Upper Huronian, Lower Huronian and Basement Complex on the north shore of Lake Huron;* by RAPHAEL PUMPELLY and C. R. VAN HISE.

DURING the past summer we visited the north shore of Lake Huron in order to find evidence, first, as to whether the Original Huronian of Logan and Murray is divisible into two series as recently advocated by the late Professor Alexander Winchell; and, second, to ascertain more definitely the relations which obtain between the Lower Huronian and the Basement Complex of the region, usually called Laurentian. The term Basement Complex is here preferred in order to avoid a discussion as to any correlation with the original Laurentian rocks.

Relations of the Upper and Lower Huronian.

Prof. Winchell found, as he thought, evidence of two series in the Original Huronian near Echo Lake. At this place, according to him, there is in descending order, a slate-conglomerate and quartzite with a dip of about 20°. There is then an interval of a third of a mile, after which appears a quartzose slate-conglomerate, followed by quartzite, and this by alternations of quartzite, quartz-schist, and various slates, schists and argillites, the series having a dip of 75° to 80° southwesterly, and being as a whole more crystalline than the first slate-conglomerate and quartzite. A break is consequently placed between the two, the upper series including all of the limestones and intervening formations of Logan and Murray's Huronian.*

About two miles east of Garden River is a ridge of banded blue and cream colored limestone fully 200 feet high, which may be easily found as a quarry is here located. Its strike is about N. 30° W., and its dip 45° south of west. On its steep northern slope, and underlying the limestone, is found the typical lower slate-conglomerate. The actual contact between the two was not found, although they are separated by only about 50 feet at one place. The lowest layer of limestone is very siliceous, probably indicating that the passage from the conglomerate to the limestone is a gradation such as ordinarily occurs when a change takes place from mechanical to chemical or organic sedimentation. The exposure of lower slate-con-

* A Last Word with the Huronian; Alex. Winchell: Bull. Geol. Soc. America, vol. ii, pp. 114–124.

glomerate was not sufficiently large to enable one to determine strike or dip.

Passing now a few paces south of the main limestone ledge, i. e., geologically upward, the actual contact between it and the upper slate-conglomerate is seen, although for no great distance. This contact is perfectly sharp. Upon one side of the line is the typical limestone; upon the other is the coarse conglomerate. The bedding of the latter is not sufficiently distinct to determine whether between the two formations there is a discordance. Above the contact occurs a good sized exposure of upper slate-conglomerate. This contains innumerable characteristic fragments of this formation, including besides various granitic fragments those of basic eruptives, of quartzite and of jasper. The distinctive feature of the exposure is, however, the presence of very numerous fragments of limestone, which sometimes reach a foot or more in diameter. These fragments have precisely the appearance of the strongly laminated underlying limestone. The bandings of the fragments lie in various directions, showing that this structure existed in the original rock at the time of the deposition of the conglomerate.

About 40 rods east, while the typical upper slate-conglomerate was not found, at the extreme southernmost part of the limestone bluff is a limestone-conglomerate or recomposed limestone, which is regarded at this point as the base of the upper slate-conglomerate.

A large exposure of lower slate-conglomerate some distance to the west of the locality above described shows the bedding to be vertical. It also has a cleavage in several directions so that large fragments under slight blows break into polygonal blocks. As compared with the upper slate-conglomerate it is much more crystalline. Its finer grained phases pass into a siliceous schist. The outcrop of lower slate-conglomerate adjacent to and north of the limestone has the same lithological character as the large bluff to the west.

It is concluded from the above observations that bearing in favor of a considerable break between the Upper and Lower Huronian are the following points:—There is (1) a difference in degree of metamorphism. The Lower Huronian has been so much altered as to have become semi-crystalline and to take on various cleavages, while the upper slate-conglomerate has no such characters. (2) Blocks of limestone in the upper slate-conglomerate are in exactly the same condition as in the original ledge. (3) Also the jasper fragments here contained were probably derived from the hematitic jaspery formation which is known to occur in the Lower Huronian. This sedimentary formation, like the limestone, belongs to one series, while the

series which contains them as detritus is of later age. The existence of jasper fragments in the Red Jasper Conglomerate was interpreted by Logan as "showing their derivation from a more ancient stratified rock."

Thus, so far as evidence was found by us, it bears in the same direction as the facts cited by Dr. Winchell, except that we would place the unconformity in the Huronian above the lower limestone member, whereas he places it below this formation. The Lower Huronian series would then comprise, in ascending order, Logan and Murray's Nos. 1 to 4 inclusive, the whole being according to these authorities about 5000 feet thick; while the upper series would comprise Nos. 5 to 13 inclusive, the whole being about 13,000 feet thick.*

Relations of Lower Huronian to the Basal Complex.

Contact near Garden River.—On the left side of the road leading from the Canadian Sault Ste. Marie, to Garden River, is a huge bluff of lower slate-conglomerate which has a north and south extent of at least an eighth of a mile. This conglomerate has all of the features heretofore described, that is, a vertical bedding, cleavages in various directions, and a semi-crystalline character. In passing from south to north the contained fragments as a whole increase in magnitude, although even after the exposure becomes strongly conglomeratic other layers lower down may be found which are nearly or wholly free from coarse detritus. When the north end of the exposure is reached the rock has become a magnificent basal conglomerate, consisting almost wholly of granite fragments set closely together and forming a stucco. The sparse fine-grained matrix is here composed of materials largely indentical with the coarse fragments. Mingled with the numerous great bowlders some of which are several feet in diameter are other bowlders of intermediate sizes. In the passage from south to north along the bluff there is also noticed a tendency for the bowlders to become angular. Turning now around the northwest corner of the ledge, and following along its foot to the east, there appears just north of a sharp ravine not more than 100 steps from the conglomerate a great bluff of massive red granite (the syenite of the early Canadian geologists). On the talus slope of this bluff were found numerous angular blocks which are a genuine recomposed granite. These on their freshly broken surfaces so closely resembled the solid ledge that they can not be discriminated from it, but on the weathered surface their complex character is readily recognized since the discrete fragments of which they are composed stand out

* Geology of Canada, 1863, pp. 55–57.

sharply. The granite of the ledge, the fragments of the recomposed granite, and the great majority of those of the conglomerate are of identical character. Although the actual contact between the granite and conglomerate was not seen, there can be no doubt that here was an old shore line and that the granitic debris of this lower slate-conglomerate was derived from the granite, this being a pre-existent ledge. A second visit to this place was made by us in the company of Dr. Charles Barrois, Dr. Hans Reusch, Dr. Carl Schmidt and Dr. Th. Tschernyschew. After having carefully examined this and another adjacent locality in which the relations were somewhat obscure, these gentlemen all agreed that the above is a correct interpretation of the facts.

This contact is not between the lowest formation of the Original Huronian of Logan and Murray and their Laurentian, but is at the base of their lower slate-conglomerate, that is, is below a member of the Lower Huronian series. When it is considered that granitic rocks do not originate at the surface, but must have been deeply denuded before they can yield blocks to a basal conglomerate it may be considered a certainty that at Garden River, there is a physical break of great magnitude between the Lower Huronian series and the basement rocks of the region.

Contact east of Thessalon.—A locality four or five miles east of Thessalon visited by the late Prof. Irving and the junior writer in 1883, and described by Prof. Irving in 1887,* was again visited by the writers last summer. Prof. Irving states that this place shows a true unconformity between the Huronian and the Archean. He describes and figures a granitic and gneissic basement complex upon which rests, with actual contact exposed, a great conglomerate, the debris of which is derived from the immediately subjacent rocks. While in 1883 the basal conglomerate was seen on a magnificent scale, the contact was found only for a few feet at the end of one island.

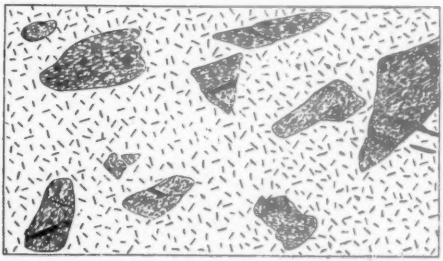
At our recent visit to this locality the water of Lake Huron was very low, at least three feet lower than in 1883. The contact instead of being exposed only for a few feet at one place was seen all the way across two low, dome-shaped glaciated islands, the length of contact in each case being 40 or more feet. The facts observed are as follows:

The lowest rocks of this vicinity were found not to be simply a granite or granitoid gneiss as might be inferred from the general descriptions of Logan, but are an intricate mixture of granites, granitoid gneisses or foliated granites, and various

*Is there a Huronian Group? R. D. Irving: This Journal, III, 1887, vol. xxxiv, pp. 207–216.

crystalline schists. A gray granite-gneiss and a red granite occurs in considerable masses, as do also dark colored schistose rocks. Here the fine-grained gneisses and crystalline schists have been most intricately intruded by the granite, and later still both have been cut through and through by pegmatitic granite. In passing from a granitoid exposure to a schist exposure the first evidence of the schists is the appearance of angular and partly rounded inclusions of these rocks. In passing onward there appear very numerous blocks of the schist which have been free to move, and the laminations of which strike in various directions, although there is often a rough parallelism in their structures. (See figure 1, drawn from a photograph.) The schistose blocks have been more or less absorbed and the whole has a pseudo-conglomeratic appearance which is identical with pseudo-conglomerates of a similar origin described by Lawson about Rainy Lake.* In passing onward towards the schistose area the intrusive granite has cut across the lamination of the schists and parallel to them so as to make a network of intrusive dikes; but the schistose material has not greatly moved from its original position, consequent upon which there is a parallelism of structure. In passing still onward the schists are cut by veins or dikes of granite, but in subordinate quantity, and finally the continuous schists are found (lower part of fig. 3.) No observing geologist would take these intrusive relations and pseudo-conglomerates to indicate that the schists are later than the granite-gneiss. Such doubtless are the relations described by Barlow,† as a consequence of which he drew the conclusion that nowhere on the north shore of Lake Huron are any detritals which are later than and rest unconformably upon the basement complex. If we understand his descriptions, he regards the dark-colored crystalline schists as Huronian, whereas they are really pre-Huronian. Seeing facts of one kind and

FIG. 1



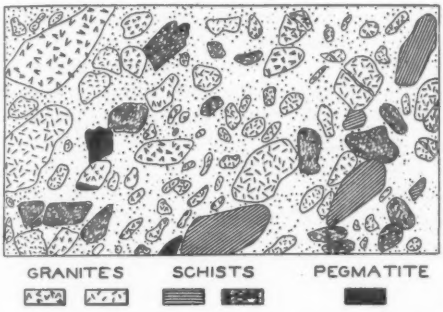
* Report on the Geology of the Rainy Lake Region, Andrew C. Lawson, Geol. and Nat. Hist. Survey of Canada, vol. iii, 1887, pp. 130F–139F.

† On the Contact of the Huronian and Laurentian Rocks North of Lake Huron, Alfred E. Barlow: Am. Geol., 1890, vol. vi, pp. 19–32.

failing to find those of another, Barlow erroneously concluded that the latter do not exist.

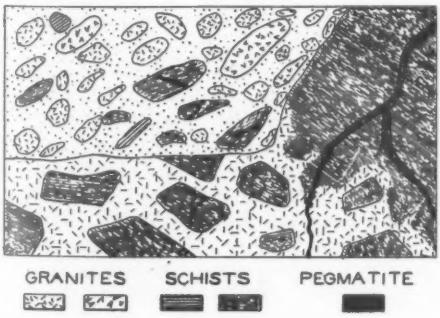
However, resting upon the crystalline complex east of Thessalon as a basement is the great conglomerate described by Irving. This conglomerate contains numerous bowlders of the red and gray granite, of the pegmatitic granite, and of the various crystalline schists derived from the immediately subjacent basement complex, as well as other materials not noted as occurring in this vicinity. The character of this conglomerate is shown by figure 2, drawn from a photograph. How different this true conglomerate is from the pseudo-conglomerate may be seen by comparing figures 1 and 2. In figure 1 the fragments are all alike and the same as the adjacent schist, while those of figure 2 have great variety and are more rounded. Also, although not possible to represent it in figure 2, the matrix is fragmental while in the other case it is crystalline granite.

FIG. 2



The line of contact between the true conglomerate and the basement complex across one island is so distinct as to be located to the fraction of an inch. This line is irregular and in one place varies in strike within a foot or two as much as 45° or 50° (see fig. 3). At places upon the lower side of this line is the gray granite, at other places are the schists, the two having the relations before described, and both are cut by the pegmatite granite. At one place the foliation of the crystalline schist or gneiss abuts perpendicularly against the line of contact. Along the

FIG. 3



line of contact between the basal complex and the true conglomerate, the pseudo-conglomerate also occurs, the fragments being all of one kind, that is derived from the schists intruded.

Above the line of erosion-contact, within an area of a square yard, in the true conglomerate may be seen fragments of the various rocks which occur in the basal complex; granites, gneisses and schists of various sorts, all of them showing the characteristic appearance of water rounding.

Upon the second island the relations are somewhat different from those just described. Here, in passing from the undoubted conglomerate on one side to the granite on the other, is an apparent transition. As the line of contact is neared, the bowlders of the conglomerate which are at first of many varieties gradually become more and more predominantly of the kind of granite which is immediately subjacent. Upon getting closer to the contact these bowlders are found to be angular and finally to have moved but little from their original positions. Finally a transition zone between the conglomerate and the granite-gneiss differs only from the solid mass of the latter in being cut by cracks into which detritus has sifted, and then these gradually die out and we are upon the solid granite. The change from unmistakable conglomerate to the solid granite takes place in about six feet. The facts here are in perfect accordance with those heretofore described, only there is the difference that the forces of erosion were not powerful enough to sweep all the coarse debris sharp and clean away from the shore line at this point, but at the beginning of the deposition of the conglomerate, left the blocks of granite and the perhaps somewhat altered granite practically undisturbed. As the sedimentary deposit increased in thickness, more and more material came in from the outside until the conglomerate took on the ordinary phase.

This contact east of Thessalon is of unusual importance because of two things: First, it is the only locality known to the writers where may be seen together the intrusive relations so well described by Lawson between granite-gneisses and dark colored schists producing pseudo-conglomerates and immediately adjacent to this complex a phenomenon of a wholly different order, a true basal conglomerate which marks the beginning of a new series. Second, this locality is important because the contact is between the lowest member of the original Huronian as described by Logan and Murray and their Laurentian of the North Shore of Lake Huron. Before reaching Thessalon, in going from west to east along the coast, we pass Logan and Murray's lower slate-conglomerate and below this their white quartzite. After passing Thessalon

there appears below these, division 2, from the base upward, of the Original Huronian, the greenish chloritic and epidotic slate group, which has been shown by Irving to be a surface volcanic.* Below this is found formation 1, the gray quartzite which grades down into the conglomerate just described.

This locality then gives decisive evidence of an erosive unconformity between the lowest member of the Original Huronian and the Basement Complex. The intricate history written in the contorted gneisses and schists, in their intrusions by granites, in the subsequent pegmatization of both, is evidence that a great length of time was taken for the genesis of the basement complex. Then a deep truncation must have occurred before these granites could be found as surface rocks. Finally an orographic movement depressed the crystalline complex below the sea and the basal conglomerate and gray quartzite are the opening chapter of the Huronian. It is then manifest that the time gap represented by the unconformity between the Basement Complex and Huronian is of the first magnitude.

General.—As a result of our observations it is evident that at two distant points, one near the west end of the Original Huronian area and the other near the east end, are great physical breaks between members of the lower division of the Huronian and a more ancient crystalline complex which was designated by Logan and Murray as Laurentian. The nature of these breaks is such as to make it impossible that they can have been local, and the conclusion therefore appears warranted that in the typical district mapped in detail by Logan and Murray, between the Huronian and the Basement Complex there was an immense period of time. As further evidence of this break is the very different lithological characters which the Huronian and basal complex have. In the latter are known no rocks which have been demonstrated to be of sedimentary origin or even surface volcanics, while many of them are plainly deep-seated igneous rocks. The major part of the Huronian rocks, on the other hand, are so little altered that their fragmental character is generally seen in the field, and is always evident at a glance when the rocks are examined in thin section. Finally, the igneous rocks associated with these detritals are in large part surface volcanics.

If the foregoing conclusions are correct, it follows that the pre Keweenawan rocks of the north shore of Lake Huron are separable by unconformities into three series; a Basement Complex, a Lower Huronian and an Upper Huronian. These

* Is there a Huronian Group? R. D. Irving. This Journal, III, 1887, vol. xxxiv, p. 210.

divisions in their order, essential characters, and manner of separation, are exactly analogous to those on the south shore of Lake Superior,* and northwest of Lake Superior at Steep Rock Lake† as shown by Smyth. Is it not then highly probable that the unconformities at these different districts are the same and that the respective series are or once were continuous for the great triangular area between them, including much of the Lake Superior-Lake Huron region.

U. S. Geological Survey,
Madison, Wis., January, 1892.

ART. XXVIII.—*A Phasemeter;* by JOHN TROWBRIDGE.

CERTAIN investigations in magnetism have led me to adopt an instrument which I have termed a Phasemeter and which, it seems to me, is destined to be of use in determining questions of the phase of alternating electric currents in transformers and in branch circuits. This instrument makes use of the method employed by Lissajous to study the vibrations of tuning forks, and afterwards adopted by Helmholtz in his vibroscope. Two telephone diaphragms are provided with mirrors. A beam of light is reflected in such a manner that the vibration of one telephone diaphragm gives a spot of light a horizontal motion, the second telephone gives the spot of light a vertical motion, and the combination of the movements of both diaphragms gives a figure which indicates the relative amplitude of the motions of the diaphragms and also the difference of phase of the currents which set the diaphragms in motion.

At first I employed a system of levers to amplify the motions of the diaphragms. The liability of the levers to communicate vibrations peculiar to themselves and thus to superimpose sympathetic vibrations on the diaphragms led me to abandon this system, and to affix a stylus to the center of the telephone diaphragm which touched a little mirror which was delicately placed on a hardened steel point on which it could rock. This method of amplifying the motions of a telephone diaphragm was employed by Professor Eli Blake, of Brown University in 1878.‡ It is a very sensitive arrangement, and I soon perceived that the mirror and its supports needed to be care-

* This Journal, III, vol. xli, pp. 117 to 137, An Attempt to Harmonize some Apparently Conflicting Views of Lake Superior Stratigraphy, C. R. Van Hise.

† This Journal, vol. xliii, pp. 317 to 331, Structural Geology of Steep Rock Lake, Ontario, Henry Lloyd Smyth.

‡ This Journal, vol. xvi, 1878.

fully tuned to the note to which the diaphragm was to respond. Herr Wien, in a late number of Wiedemann's Annalen, has adopted practically this method of Professor Blake, in what he terms an optical telephone for the measurement of alternating currents.* Herr Wien has added peculiar attachments in order to bring the mirror holder into unison with the note given out by the diaphragm. The following arrangement which I have adopted, although it is less sensitive than the arrangement of Professor Blake and Herr Wien, seems better suited to the instrument which I have termed a phase-meter. Two Bell telephones were provided with diaphragms of three inches in diameter; these diaphragms were not clamped equally around their edges, but were tuned to the note given out by the alternating current employed by touching the diaphragm at its edges, at suitable points, by means of clamps which could be moved around the edge of the diaphragm until a mirror attached to the diaphragm showed that the latter moved in unison with the current. By turning the telephones around the axis of their magnets the vibrations of the mirrors are adjusted so that they take place in planes at right angles to each other. Thus when one telephone is cut out of the circuit the other gives a straight line of light, indicating that the mirror is moving in unison with the diaphragm.

As a source of light I have found it convenient to employ the Welsbach burner, which consists of a zirconium gauze mantel placed over the ordinary Bunsen burner. This gives a very steady and intense source of light. A tin chimney is slipped over the glass chimney. In the tin chimney is a circular opening of one half inch in diameter. Over the tin chimney, in turn is slipped, so as to fit it closely, a thin white paper chimney, and a pin hole is made in this paper at the center of the orifice in the tin chimney. This arrangement enables one to see the figures produced by the movement of the two telephones against the cross hairs of the observing telescope. Moreover the field of view being thus illuminated the disturbing phenomena of diffraction are almost completely eliminated and a clear bright image of the pin hole is obtained.

The apparatus can be made very compact, and the two telephones with the observing microscope or telescope can be all contained in a box a foot square. With a screen at a distance of twenty feet the figures can be produced of such a size that an audience in the large lecture room of the Jefferson Physical Laboratory can easily perceive them, and note their changes of phase.

*Das Telephon als optischer Apparat zur Strommessung. Wied. Ann., xlii, p. 593, 1891.

It is well known that it is necessary to employ two or three electrodynamometers to detect magnetic lag and changes of phase in the subject of alternating currents of electricity. The phasemeter shows changes of phase which I believe can not be observed in any other way, and I think it will be of especial use in the study of hysteresis. I am employing it at present in the study of the propagation of magnetic disturbances around rings and over straight bars of steel and iron, and have obtained some interesting results which will form the subject of a subsequent paper. The changes of phase which occur on a ring of iron between two magnetizing bobbins with the same or opposite poles, opposing each other and excited by alternating currents of high frequency, are of extremely interesting character, and can as I have already remarked be clearly shown to any audience.

Jefferson Physical Laboratory, Cambridge.

ART. XXIX.—*Preliminary Report of Observations at the Deep Well, Wheeling, West Virginia;* by WILLIAM HALLOCK. (Abstract.)

THE question as to the conditions which exist in the interior of the earth has always attracted much attention. The most important factor in the solution of this riddle is the determination or estimation of the temperatures there existing. The British Association has for years, seized every opportunity to obtain data as to the rate at which the temperature increases as the earth crust is penetrated. The most recent and reliable contributions on this subject are by Mr. E. Dunker of Halle, Germany, and were obtained from a 4170 foot well at Sperenberg not far from Berlin, and a 5740 foot well at Schladabach near Leipzig.

These wells are both full of water, the circulation of which vitiates results or renders elaborate apparatus indispensable, and the thermometers must be protected from the pressure.

The Wheeling deep well, sunk by the Wheeling Development Company and by them generously dedicated to science, is 4500 feet deep, $4\frac{7}{8}$ inches diameter and *dry;* cased only to 1570 feet. The strata there are nearly *in situ*, undistorted and dipping only 50 feet to the mile. More satisfactory geological conditions can scarcely be imagined.

Being dry, ordinary U. S. Signal Service maximum thermometers were used and no especial precaution needed to be taken to prevent circulation of the air. The thermometers

were lowered and raised, and depths measured by a steel wire. Results:

TABLE I.

Depth feet.	Temperature Fahr.	Depth feet.	Temperature Fahr.
1350′	68°·75	3125′	88°·40
1591	70·15	3232	89·75
1592	70·25	3375	92·10
1745	71·70	3482	93·60
1835	72·80	3625	96·10
2125	76·25	3730	97·55
2236	77·40	3875	100·05
2375	79·20	3980	101·75
2486	80·50	4125	104·10
2625	82·20	4200	105·55
2740	83·65	4375	108·40
2875	85·45	4462	110·15
2990	86·60	———	———
		100′	51°·30

These observations when plotted show a slow increase for the upper half of the uncased portion, about 1° F. for 80 to 90 feet, whereas the lower part shows a more rapid increase, about 1° F. for 60 feet. The whole series gives a well defined and regular curve, with a deflection at 2900 to 3000 feet where an oil sand occurs. Practically all the rest of the uncased well is in shale. The increase in the rate at which the temperature rises as the bottom is approached can only be temporary or we should have an inconceivable or improbable state of temperature at comparatively slight depths.

The two distinct series of observations combined in Table I nowhere disagree more than 0°·3 F. and hence are very reliable and accurate.

Table II gives comparison of the results at the three great wells.

TABLE II.

Name of Well and Location.	Feet for 1° F.	Total depth.	Temp. at top.	Temp. at bottom.
Sperenberg, near Berlin,	59·2 ft.	4170 ft.	47°·8	118°·6
Schladabach, near Leipzig,	65·0 "	5740 "	51 ·9	135 ·5
Wheeling Development Co.,	-----	4500 "	51 ·3	110 ·3
Top and greatest depths,	74·3 "	"		
Mean of lower 3000 feet,	75·4 "	"		
Mean of above two,	74·9 "	"		

Inasmuch as the bottom of the well is some 3700 feet below sea level, it seemed worth while to attempt barometer readings in it. The instruments used proved ill adapted to the work

and the results were unsatisfactory. Samples of air were taken at the bottom but could not be analyzed in time for use.

A series of observations in a coal mine near the well gave as a very probable value of the temperature of the top invariable stratum 51°·3 F. From the mean annual temperature of Marietta and Steubenville it might be taken at 51°·5 F.* Drilling is temporarily stopped, but we hope to go 5500 or 6000 feet. Mr. Anton Reyman of the Development Company has generously guaranteed half the expenses and we are waiting for a lucky man to furnish the other $3000, and enable the Wheeling well to be lifted from the second to the first place among the deep wells of the world.

The gratitude of the scientific world is due to the Wheeling Development Co. who ordered and paid for the well, to T. S. Kinsey who drilled it, and to Prof. I. C. White who discovered it and induced its owners to dedicate it to science.

ART. XXX.—*Mount Bob, Mount Ida, or Snake Hill;* by T. W. HARRIS.

WHEN a series of stratified rocks, extending over a wide area, is long exposed to the destructive activities of the weather and other erosive agencies, it is gradually removed, first along the courses of the principal streams, then along their smaller branches, and finally, at a decreasing rate, from the back country, on which, however, small scattered outliers may long remain, marking the former extension of the now almost destroyed formation.

In eastern New York, a number of such small outliers mark thus the former eastward extension of the Helderberg limestones, nearly to the foot of the Berkshire Hills. Several of these are mentioned by the State Geologists of New York. Two, lying east of the Hudson River, near the city of Hudson, are given especial prominence by W. W. Mather, in the volume of the Natural History of New York descriptive of the Geology of the First District (Albany, 1842), under the names, respectively, of Becraft's Mountain and Mount Bob. The structure and relations of the former, have also been fully described in this Journal (vol. xxvi, 1883, p. 381) by Mr. W. M. Davis, of Cambridge.

Sometime ago I visited the latter outlier, and found it to be in general of similar character to Becraft's Mountain, as described by Messrs. Mather and Davis, though of smaller area, and simpler structure. Mr. Mather says of it—

* As reduced by Chas. A. Schott, U. S. Coast and Geodetic Survey.

"Mt. Bob, so-called, is a hill about one hundred feet high, in the northwest part of Claverack, Columbia County. The west side is very steep, and a slope of debris of the blue, compact limestone, conceals a part of the rock of the same kind, which rises about twenty feet in a mural escarpment, and dips to the east, as is represented on Plate 38 [see fig. 1], where (*a*) is the blue limestone, and (*b*) and (*c*) strata of gray fossiliferous limestone like that of Becraft's Mountain. The slate underlies, apparently unconformably." (Nat. Hist. of N. Y., Part IV, Geol. of First Dist., p. 351.)

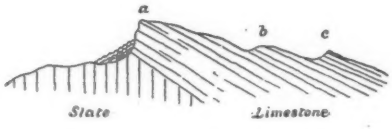
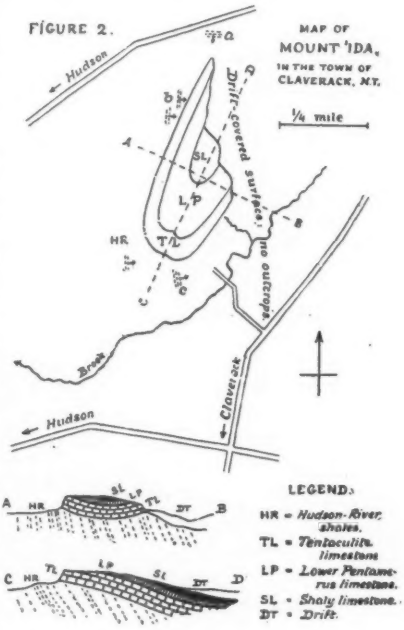


FIGURE 1.

The name, "Mount Bob," has apparently now gone out of use in the neighborhood, and the outlier is known in Hudson as "Snake Hill," and among the farmers in the immediate vicinity as "Mount Ida." The limestones form a wooded elevation about half a mile long by a quarter broad, which rises at the southern end in a steep cliff, one hundred feet or more above the gently rolling, drift-covered plain encircling it, but slopes gently down to the north. In structure, it forms a fragment of a northeastwardly plunging syncline, and consists of the three lower members of the Lower Helderberg group. The great mass of the hill consists of the thin-bedded strata of the Tentaculite or Ribbon limestone, about eighty feet in thickness. No fossils were found in these but a few imperfect *Leperditiae*. Above this, and inside the crest of the cliff, were about twenty feet of the Lower Pentamerus limestone, coarse, gray and irregularly bedded, in which a few specimens of the

FIGURE 2.



characteristic *Pentamerus galeatus* were found. In the center of the hill was a small patch of brownish-gray, shaly material in which a few specimens of *Spirifer macropleura* and *Strophomena rugosa* were found; apparently representing the Delthyris or Catskill shaly limestone. The axis of the syncline courses about N. 35° E., and its plunge is about 20°. To the north it disappears under a heavy mass of drift. The dip on the east side averages 25°; on the west, 20°.

The underlying strata, which appear at several points about the base of the hill, are of a soft gray shale, without fossils, but resembling in appearance the rocks which occur throughout this part of the Hudson valley, and are known as the Hudson River group. The shale has a well-marked cleavage, which appears parallel to the stratification wherever the latter can be distinctly made out. The strike varies from N. 90° E., at the northern end of the hill, to N. 5° W., at its southern end, the dip being always very steep. The question of the conformity of the limestone upon the shale was considered, and a careful search made for their junction; but this was everywhere covered, the nearest approach of the two rocks being about fifty feet, on the west side of the hill, at *b*, fig. 2. Here the limestone had a strike of N. 30° E. and a dip of 22°; the shale, striking N. 8° E., and dipping 60° E. Near the southern end of the hill, the strike of the shale, at *c*, fig. 2, was N. 5° W.; its dip, 45° E. At the northern end of the hill (fig. 2, *a*) the strike of the shale, here very distinct, was about N. 90° E. (varying about 60° from that of the limestone), and its dip 80° S.; but the distance between them being some four hundred feet, it is quite possible that the limestone, if restored, might be found to come into parallelism with the shale within that distance. But although the question of conformity cannot be fully settled from these outcrops, the general lack of accordance between the strikes of the shales and of the limestones, would seem here, as at Becraft's Mountain, rather to favor unconformity, and to suggest that the limestones were laid down upon the upturned and eroded edges of the shales, probably over an area extending far from the outlier in all directions. Since then, erosion has removed most of the limestone, this fragment owing its preservation perhaps to its place in the bottom of a syncline deeper than the average, and hence the last to be reached by the levelling forces; and perhaps also in part to a local increase in the thickness of the hard Tentaculite limestone, if we may take the thicknesses of that member at Catskill (seventy feet) and Becraft's mountain (forty to fifty feet) as average measures.

Cambridge, Mass.

SCIENTIFIC INTELLIGENCE.

I. Physics and Astronomy.

1. *The Variation in the Density of Water with the Temperature.*—D. Mendeléeff in an exhaustive paper discusses the results of previous observers, and points out that the formula $S_t = 1 - \frac{(t-4)^2}{(A+t)(B-t)C}$ obtained by him appears to embrace all that is known of the variations of the density of water between $-10°$ C. and 200° C. with the accuracy that is now attainable. He points out that if fresh determinations of greater accuracy should confirm the accuracy of this formula, or lead to a more correct formula, we may hope to arrive at a better understanding of the true law of the expansion of all liquids and also of gases. By means of investigations upon water we may hope to make further progress in the study of matter under the influence of rise of temperature.—*Phil. Mag.*, Jan., 1892, pp. 99–132. J. T.

2. *On a New Method of obtaining a Constant Temperature.*—Mr. Henry Clew has employed an electrical current in the following manner. The current from a certain number of storage cells is led through a fine covered wire of high specific resistance, which is coiled about the glass vessel in which the temperature is to be maintained. The glass vessel is contained in a suitable calorimeter. In one experiment the temperature was maintained constant within $\frac{1}{100}$ of a degree for 40 minutes and the author believes that much greater constancy can be obtained.—*Phil. Mag.*, Jan., 1892, p. 89–93. J. T.

3. *Velocity of Sound in membranous bodies.*—L. Melde has obtained the velocity of sound in membranes of various natures by taking strips of the membranes. These were fastened at both ends and were rubbed in the middle. A table of the results is given and shows a great difference in the propagation of sound in various substances.—*Beiblätter, Ann. der Physik und Chemie*, No. 11, 1891, p. 756. J. T.

4. *A Surface Bolometer.*—At a meeting of the Physical Society held in Berlin, Jan. 8, Dr. Kurlbaum described a surface bolometer. It is cut out of platinum foil whose thickness is 0·012 mm. and possesses the great advantage of coming to rest quickly. It is a trustworthy instrument for measuring the difference in luminosity of two sources of light.—*Nature*, Jan. 28, 1892. J. T.

5. *Orthochromatic Photography.*—MM. Fabre and Andoyer photographed the eclipsed moon at the Toulouse Observatory on Nov. 13, 1891. They employed collodion-bromide and collodion-chloride plates which were stained either with eosin or cyanine. The collodion bromide plates were relatively more sensitive to red and yellow than the collodion-chloride plates.—*Nature*, Jan. 21, 1892. J. T.

6. *Prize for Researches in Physics.*—For the year 1894 a prize is offered by "Schnyder von Wartensee's Foundation for Science and Arts" at Zürich, for the solution of the following problems in the domain of physics:' "As the numbers which represent the atomic heats of the elements still show very considerable divergences, the researches conducted by Professor H. F. Weber on boron, silicon and carbon, regarding the dependence of the specific heats upon the temperature, are to be extended to several other elements, prepared as pure as possible, and also to combinations or alloys of them. Further, the densities and the thermic coefficients of expansion of the substances investigated are to be ascertained as carefully as possible."

The treatises handed in by competitors for the prizes may be in German, French or English, and must be sent in by September 30, 1894, to the address given below. They will become the property of the Foundation. Every treatise must have a motto on the title page, and be accompanied by a sealed envelope bearing the same motto outside and containing the author's name. The Prize Committee is empowered to award a first prize of two thousand francs, and minor prizes at its discretion to the amount of one thousand francs. *Address:* "An das Praesidium des Conventes der Stadtbibliothek Zürich (betreffend Preisaufgabe der Stiftung von Schnyder von Wartensee für das Jahr, 1894)."

7. *Astronomical Expeditions to Peru.*—In the annual report for 1891 of the Director of the Astronomical Observatory of Harvard College, an account is given of the expeditions sent to Peru in 1889 and again in 1890, at the expense of the Boyden Fund, as follows: "The expedition sent to Peru in 1889 under the direction of Mr. S. I. Bailey, having successfully completed the observations with the meridian photometer, returned to Cambridge with that instrument, which has been remounted here and will be used for a revision of the Harvard Photometry and for other photomeric work. During the two years ending May 1, 1891, Mr. Bailey took 217 series of observations and made 98,756 photometric comparisons of about eight thousand southern stars. These include all the stars of the sixth magnitude and brighter south of —30°, and all known catalogue stars in a series of zones 20′ wide at intervals of 5° in declination from —25° to —80°; also all known stars south of —80° and a miscellaneous list of variables, stars having peculiar spectra, etc. The reduction of these observations is nearly completed and their publication will be begun shortly. A large part of the work assigned to the Bache telescope has also been completed, and the instrument has been remounted at Arequipa where its work will be continued.

"An expedition under the direction of Professor William H. Pickering left Cambridge in December, 1890, and established a station about three miles northwest of Arequipa, where the thirteen-inch equatorial has been mounted. This station has an elevation of a little over 8000 feet and has a nearly cloudless sky during a large part of the year. The air is remarkably steady,

the images of the stars are small and round and the diffraction rings, seldom seen with large instruments, are clearly visible. Even with high powers the fluctuations of the images are very slight. In fact, at this station the limit to observation will probably be the size of the instrument, instead of, as at other observatories, the condition of the air. Although the aperture of this instrument is only thirteen inches, it appears to be the largest refracting telescope in use in the southern hemisphere, while about thirty larger telescopes are mounted in the northern hemisphere. Since all of these instruments are north of $+35°$, nearly one-quarter of the entire sky, and that containing many objects of the greatest interest, has never been studied by a refractor of the highest grade. For both these reasons an excellent opportunity is afforded to add to astronomical discovery by the erection of a telescope of large size at this station. It is hoped that patrons of astronomy will consider the advantages of erecting a large telescope where it will be kept constantly at work, where the sky is clear a large part of the year, where the condition of the air is probably more favorable than at any other existing observatory, and where a large part of the sky could be examined for the first time under such satisfactory conditions. Photographs have not yet been obtained with the thirteen-inch telescope, but it is hoped that its advantages for this kind of work will be as great as for visual observations."

8. *On the Causes of the Phenomena of Terrestrial Magnetism* and on some Electro-mechanism for exhibiting the secular changes in its horizontal and vertical components, by HENRY WILDE.—This paper from the *Philosophical Transactions* presents the author's views on the nature of terrestrial magnetism. These will be evident from his statement of the three successive stages in the earth's history, which he assumes, and which he illustrates by a large globe with its surface wound with copper wire. These stages are (1) The electro-dynamic condition of the terrestrial globe at a period of its history when the crust from its high temperature was non-magnetic, its surface of uniform curvature and the electro-dynamic foci of the internal sphere of vapors inclined at a definite angle from the poles of the earth's axis.

(2) The electro-dynamic and electro-magnetic condition of the earth when its outer crust was uniform in curvature and had cooled down sufficiently to become permanently magnetic with dual foci of intensity coincident with the poles of the earth's axis and separate from the dual polar foci of the internal sphere of vapors.

(3) The unsymmetrical distribution of the magnetic elements arising from the unequal curvature and foldings of the earth's crust during its secular cooling as indicated by the present distribution of land and water on the terrestrial surface.

As shown in the above, the author finds the seat of the earth's magnetic attraction in the earth's crust and explains the unsymmetrical distribution of the terrestrial magnetism by the irregular configuration of the earth as manifested by the distribution

of land and water on its surface. This was illustrated by experimental methods, the ocean areas of the mapped globe being covered with a thin sheet of iron, roughly contoured to the coast lines of the continental areas; a close agreement with the unsymmetrical lines of declination was obtained. A further cause of magnetic asymmetry is sought for in the diamagnetism of the waters of the globe and of the compounds of the alkaline metals which they hold in solution.

9. *The Astronomical Handbook for the year* 1892. 38 pp. 12mo. Brooklyn, 1892.—This little handbook and ephemeris, prepared under the direction of the Executive Committee of the Department of Astronomy in the Brooklyn Institute of Arts and Sciences, will be found useful particularly by all persons—even if they have not a full scientific training—who are interested, as amateurs, in astronomy and in studying celestial phenomena. It gives information in regard to eclipses, the positions of the planets, notes on the double stars and so on, with suggestions as to special observations which individuals may make with interest and profit. It is also stated that the President of the Department (Garrett P. Serviss, 8 Middagh st., Brooklyn) will give information and advice to those not able to attend the meetings.

II. Geology and Mineralogy.

1. *Honor to the United States Geological Survey from the French Academy of Sciences.*—The Academy of Sciences of France at its last Annual Session, on the 21st of December, conferred on the United States Geological Survey the Cuvier prize. The commissioners of the Academy—consisting of MM. Gaudry, Fouqué, de Quatrefages, Milne Edwards, with M. Daubrée, Reporter—state in their report with reference to the prize:

"L'œuvre du Geological Survey, avec le magnifique ensemble de travaux qu'elle comprend, mérite donc que nous lui rendions un hommage éclatant, pour la lumière si vive et si inattendue qu'elle a jetée sur l' histoire géologique et sur les richesses minerales de l' Amérique du Nord. Le prix Cuvier est décerné à cette grande œuvre collective, non seulement aux collaborateurs actuels, mais aussi à ceux qui ont dû cesser leurs fonctions. Il sera, nous l' espérons, conservé dans les archives du *Geological Survey*, comme un témoignage de la haute estime de l' Académie des Sciences."

These closing words of the Report are preceded by a review of the geological work carried forward by American geologists in connection with the various State surveys from 1833 onward; by the U. S. Geological and Geographical Survey of the Territories under Hayden, mentioning in detail some of the great results: the expedition of Powell along the cañon of the Colorado; the "study extremely remarkable" of the Henry Mountains by Gilbert; the Exploration and Survey of the 100th Meridian under Lieut. Wheeler, of the U. S. Department of Engineers; the U. S. Survey of the 40th Parallel under Clarence

King; and finally, with more special mention of results and of workers, the existing U. S. Geological Survey, organized by Clarence King in 1879, and placed the following year under the directorship of Major Powell, and from the first carried forward over all parts of the continent "even the most inhospitable," with an energy that "recalls the heroism of an army attacking obstacles the most arduous and most inaccessible."

2. *Geology of the Tonga or Friendly Islands.*—A valuable paper on these islands of the South Pacific, by J. J. Lister, is published in the Quarterly Journal of the Geological Society, vol. xlvii, p. 590, June, 1891. The region of the group—whose length is about 250 English miles—is remarkable for the great diversity of level in the islands and in the ocean adjoining.

On the west side, along a course nearly N.N.E., the islands, from Amargura in 18° S. and 174° 25′ W. to Honga Tonga in 20° 35′ S. and 175° 25′ W. are volcanic, and the heights occur of 1890 feet in Lette I., 151 in Metis I., 3030 in Kao, 1890 in Tofua, and 300 feet in Honga Tonga.

Just east (30 to 40 miles), along an irregularly parallel line, occur: Vavau at the north, in 18° 35′ S. and 174° W., with nothing but coral reef limestone in sight, and having on the N. and N.E. sides the limestone rock in cliffs 300 to 500 feet high; the Hapai Group, consisting mostly of coral reef rock, 20 to 100 feet high; the Nomuka Islands, consisting of tufa, having coral reefs to eastward 30 to 60 feet high; at the south end, Tóngatabú,* in 175° W. and 21° 10′ S., a coral island with a shallow lagoon, but raised 60 feet above the sea-level on the southeast side.

About 10 miles to the southeast of Tongatabu is Eua, a volcanic island over 1000 feet high at two points, but encased in coral-reef to a height at one point, by estimate, of 300 feet, and another of 500 feet, and having cliffs of the limestone "some 200 feet high" along the eastern and western sides.

Mr. Lister's paper which is illustrated by maps and sections, contains other facts of geological importance. He refers to the great depths of the sea to the southeastward and eastward of the group; to the southeastward 230 miles, in 175° 08′ W. and 24° 37′ S., 4428 fathoms, and in 175° 07′ W. and 24° 49′ S., 4295 fathoms; to the eastward of Vavau, 150 miles, in 172° 14½′ and 17° 04′ S., 4530 fathoms. On the bathymetric map in this Journal, vol. xxxvii, and also page 420, and vol. xxxix, p. 412, other soundings in the vicinity are given, but none have been obtained on the direct line between the two deep depressions.

The soundings make the total height of the summit of Kao above the deepest point in the ocean to eastward a little over 30,000 feet. Such depressions are not a result of loading the crust by deposition. The range of facts here reviewed indicate that some profounder method of causing change of level has been at work. J. D. D.

* The accent is on the first and last syllables—the latter half being the Polynesian word tabú.

3. *Notes on the Palæozoic Species mentioned in Lindley and Hutton's "Fossil Flora;"* by R. KIDSTON. (Proc. Roy. Phys. Soc. Edinb., vol. x, 1889–90 (1891), pp. 345–391).—The search for and the consultation of type specimens, which have been brought about during the last fifteen years by the renaissance of Paleozoic paleobotany in Europe and the establishment of priority in nomenclature, have keenly emphasized the need of revision of the older works and the frequent redescription of the species. Especially the results of the examination by Zeiller of a large part of Brongniart's material, and by Kidston of so much of the collections of the English authors as can be found, have shown from time to time that a considerable portion of the current identifications after the too brief descriptions and often false figures in the "Histoire" or the "Fossil Flora" not only disagree among themselves, but are totally different from the originals, while the latter, in the case of the English work, are frequently, in the present state of our knowledge, unidentifiable. Mr. Kidston's "Notes" extend his observations, previously recorded in the case of a part of the species, to the entire work, thus placing the existing types of the "Fossil Flora" in their true positions, so far as determinable, according to the judgment of the foremost English authority in this field. Among the more important correlations not so generally anticipated, are the identifications of *Neuropteris Sorettii* and *Cyclopteris dilatata* with *N. heterophylla*, to which also belong the *Pecopteris adiantoides*, and *Neuropteris heterophylla*, made *N. Lindleyana* by Sternberg on account of the incorrect and partially hypothetical figures. *Neuropteris attenuata* is a *Pecopteris* not specifically identifiable, while *Pecopteris Bucklandii* is clearly a *Neuropteris*, probably the *N. rarinervis* Bunb. Thirty-six species founded on, or identifications made from, imperfect specimens are found not to afford the necessary characters for subsequent identification. Mr. Kidston's "Notes" are valuable particularly in pointing out the inaccuracies of the plates, in which the great English work appears much weaker than its contemporaries. D. W.

4. *Correlation Papers: Cambrian;* by C. D. WALCOTT, 447 pp. 8vo. Bull. No. 81, U. S. Geol. Survey. Washington, 1891.—Mr. Walcott has here given, in his very thorough way, a review of the history of Cambrian discoveries, its synonymy, local stratigraphy in each region of its occurrence, general paleontology, subdivisions, and distribution, for North America, with citations from all descriptions or accounts and discussions of the various questions involved, and also with notes on the Cambrian of Great Britain, Europe, China, India, Australia and South America. Following the five chapters dealing with these various subjects, a sixth treats of the general principles of Correlation in geology, as it has been presented by others and as deduced by the author from his own observations.

5. *Index to the known Fossil Insects of the World, including Myriapods and Arachnids;* by S. H. SCUDDER. Bulletin No. 71.

Washington, 1891.—Mr. Scudder's bibliography takes up separately the Paleozoic species, Mesozoic and Cenozoic and gives the references in the briefest form, and still 100 pages are devoted to the Paleozoic species alone, 180 to the Mesozoic, and 500 to the Cenozoic species: so that altogether the entries make a volume of 744 pages.

6. *On the removal of gold from suspension and solution by Fungoid growths.*—Prof. A. LIVERSIDGE, of Sydney, N. S. W., states in a paper read before the Australasian Association for the Advancement of Science at Melbourne in 1890, that, he first observed in 1889 that gold was removed from solution and suspension by fungoid growths, and had since made further investigations. The gold was held in suspension in distilled water, that had been prepared at different times, the gold being reduced from a weak solution of the chloride by means of phosphorus dissolved in ether. A complete precipitation usually takes several years. Examining the bottles which had been settling since 1881, he found that in those having fungoid growths, usually at the bottom of the bottles, the liquid was colorless, but in the others the color was ruby-red or purple, the gold being still in suspension. In one bottle put up in November, 1884, having the liquid colorless, a purple-blue fungoid growth had taken place, which under the microscope was a mass of matted purple-blue filaments; but after being dried over a spirit lamp, the filaments retained their form but acquired the luster and color of gold. In 1889, other experiments were tried with more precise results. But it was found that not only moulds produce the result, but also any organic matter living or dead.

7. *Les Méthodes de Synthèse en Minéralogie* par STANISLAUS MEUNIER. 359 pp. 8vo. Paris, 1891.—The progress made in the subject of mineral synthesis has been remarkably rapid in the last two decades, and the success of the French chemists in this line has been particularly marked. The excellent books of Fouqué and Lévy (1882) and of Bourgeois (1884), which gave a full summary of what had been accomplished in the way of forming artificial minerals, are now followed by a volume by another active worker in the same field, Stanislaus Meunier. This work, however, occupies a place of its own, for it is devoted particularly to an explanation of the methods used and general principles involved. The first part discusses the contemporaneous formation of minerals in nature; and a second part is given to the cases of accidental synthesis, furnace products, etc. The third and most important division describes the method of synthesis proper; first by the dry way involving simple crystallization by molecular change, by igneous fusion and by the intervention of a mineralizer; then simple decomposition; chemical union; precipitation and finally, double decomposition. The methods of synthesis in the wet way are also described with similar system and thoroughness as also those where the method is mixed. This summary will give an idea of the wide range of topics here presented, but the volume calls for the close study that it fully merits.

8. *Brief notices of some recently described minerals:* ASTOCHITE. A kind of amphibole, near richterite, from Långban, Sweden. It occurs as a coarse crystalline, columnar aggregate, of a blue to grayish violet color. Cleavage-angle 56° 27′; extinction 15° 40′ blue to 17° 15′ violet; sp. gravity = 3·05, 3·10. Analyses by Mauzelius, are, as follows, 1 for the blue, and 2 for the violet variety:

	SiO_2	FeO	MnO	MgO	CaO	Na_2O	K_2O	H_2O	F	
1.	56·25	0·15	6·49	21·89	5·44	6·17	1·60	1·56	0·15	= 99·70
2.	54·76	0·21	12·71	17·82	5·83	4·02	1·65	2·77	0·09	= 99·86

This yields a normal metasilicate formula. Described by H. Sjögren in *G. För. Förh.*, xiii, 605, 1891.

ADELITE. A basic arsenate from Nordmark and Långban. It occurs in masses of a gray color; hardness = 5; sp. gravity = 3·76. Analyses agree closely with the composition $H_2O \cdot 2CaO \cdot 2MgO \cdot As_2O_5$, and a connection with either the olivenite or wagnerite group is suggested. Described by Sjögren, *ibid.*, p. 781.

SVABITE. A mineral from the Harstig mine, Pajsberg, referred by Sjögren (l. c.) to the apatite group. It occurs in colorless hexagonal prisms terminated by the pyramids, $10\bar{1}1$ and $11\bar{2}1$; the vertical axis is 0·7143 (apatite 0·7346). The composition is given by the formula $H_2O \cdot 10CaO \cdot 3As_2O_5$.

BOLEITE. An oxychloride of lead and copper occurring at the Boleo copper mines, near Santa Rosalia, Lower California. It occurs in cubic crystals of an indigo-blue color, which show anomalous optical phenomena; there are also crystals in tetragonal octahedral forms having the same composition. These are regarded by the describers, MM. Mallard and Cumenge, as identical, but the cubic crystals can hardly be other than percylite, only differing in containing 9 p. c. of silver.—*C. R.*, cxiii, 519, 1891.

LAUTARITE. A calcium iodate from Atacama, occurring in large prismatic crystals referred to the monoclinic system. It is colorless to yellow; sp. gravity = 4·59. Composition $Ca(IO_3)_2$, and hence belonging to a class of compounds not before represented among minerals. The same region furnishes crystals having a composition approximating to $Ca(IO_3)_2 \cdot Ca\,CrO_3$. Described by Dietze, *Zs. Kryst.*, xix, 447, 1891.

MORINITE. A phosphate of alumina and soda, not yet analyzed, occurring in monoclinic crystals with the amblygonite of Montebras, France. Described by Lacroix, *Bull. Soc. Min.*, xiv, 187, 1891.

OBITUARY.

THOMAS STERRY HUNT.—Mr. Hunt was born at Norwich, Connecticut, in September, 1826, and died in New York on the 12th of February, 1892. The year 1845 and 1846 he spent at New Haven, Conn., in the chemical laboratory of B. Silliman, Jr., who was then assistant to his father in the chemical department of Yale College. He pursued his chemical studies with great

earnestness and success. Already in 1846 he published several short chemical notes in this Journal, and in 1847 reviewed at length Gerhardt's Organic Chemistry, which had greatly interested and instructed him, besides preparing papers on some points suggested by it. The Geological Survey of Canada under Wm. E. Logan, (afterward Sir William) as Director, with Alexander Murray as assistant, had been in progress from the year 1842; and in 1847 Mr. Hunt was appointed its chemist and mineralogist. The Annual Reports for 1849–50 and the following years bear evidence of his activity in analyses of rocks, minerals, mineral waters and materials of economical value. In the Report for 1850–1, he has analyses of the minerals peristerite and bytownite of Thomson and proposes a new species, Loganite; in that of 1851–52 he describes the new species Parophite, and in that for 1852–53, he brings out Wilsonite as a new mineral.* The results of similar work make large mineralogical and petrological contributions to the succeeding volumes. In the general Report of 1863, chapters 17, 18, 19 and 20, occupying over 200 pages, are by him.

Mr. Hunt took a wide interest in the results of the Canadian Survey, and in 1849 presented at length to the American Association, and again in 1861 and 1868 to this Journal, the conclusion of Logan that the Taconic series of rocks were of Lower Silurian age; and in 1855 there was published in this Journal—anonymously, in compliance with his request—a severe review by him of Professor Emmons's American Geology. He continued his connection with the Survey until 1872, two years after Mr. Selwyn became Director. In the mean time, he also occupied the chair of chemistry at the Laval University, Quebec, from 1856 to 1862, and at McGill University, Montreal, from 1862 to 1868. From 1872 to 1878 he was Professor of Geology in the Institute of Technology, Boston.

* An error in Appleton's American Cyclopedia of Biography with reference to the introduction of the terms Laurentian and Huronian, should here be corrected in justice to the distinguished head of the Canadian Geological Survey. In the Annual Report for 1852–53, Logan says on this point, on page 8 of his special report, which is 150 pages in length, as follows: "The name which has been given in the previous Reports to the rocks underlying the fossiliferous formations in this part of Canada is the Metamorphic Series; but, inasmuch as this is applicable to any series of rocks in an altered condition and might occasion confusion, it has been considered expedient to apply to them for the future, the more distinctive name of Laurentian Series."

Then follows a list of the geological formations of Canada, in which Laurentian is followed by the Potsdam, showing that it was applied to the rocks older than the Potsdam, all of which he believed to lie unconformably beneath the Potsdam.

The term Huronian first appears in print in the Sketch of Canadian Geology, of 1855, by Mr. Logan and Mr. Hunt, prepared for the Paris Exposition. The preface of the work credits Mr. Logan with all the geological part of the volume, and the text cites from him all the characteristics mentioned of the Huronian Series. The Annual Report of the Survey for 1853–55, published in 1857, in the course of the special report of Mr. Murray for the year 1854, dated June 11, 1855, uses both the terms Laurentian Series and Huronian, in describing the rocks which he had studied the year before and conjointly with Logan in former years.

Among Mr. Hunt's various papers the following have prominence: his Presidential address before the American Association for the Advancement of Science in 1871, in which are the germs of several of his later publication; his address at the Centennial of Chemistry in 1874, on "A Century's Progress of Chemistry;" "The Chemistry of the Primeval Earth;" "The Chemistry of Natural Waters;" "The origin of Crystalline Rocks—the Crenitic Hypothesis;" "The Geological History of Serpentine." Nearly all bear the impress of an able but speculative mind, well stored with knowledge, but not well enough supplied and weighted with geological facts where the subject has a geological bearing, and not always capable of reading rightly the opinions of others when they differed from his own. His late views on the Taconic question have been sufficiently discussed in recent volumes of this Journal. His published volumes are: Chemical and Geological Essays, 1874, 1878; Azoic Rocks, 1878; Mineral Physiology and Physiography, 1886; a New Basis for Chemistry, 1887; "Mineralogy according to a Natural System," 1891.

Dr. Hunt has the credit of bringing before the American Association for the Advancement of Science in 1876, the plan for an International Geological Congress, the fifth meeting of which was held in Washington the past year. At the Bologna meeting in 1881, he was one of the twenty Vice-Presidents. He was made a fellow of the Royal Society of London in 1859, and a member of the National Academy of Sciences in 1873; and in 1881 he received from Cambridge, England, the degree of LL.D.

Sir George Biddell Airy, for many years Astronomer-Royal of Great Britain, died on January 7, in his ninety-first year. He was graduated at Cambridge as Senior Wrangler in 1823, three years later he was made Lucasian Professor of Mathematics, and in 1828 Plumian Professor of Astronomy; his appointment as Astronomer-Royal was made in 1835. His scientific contributions in the fields of mathematics, physics and astronomy, commencing in 1824, have been numerous and of high merit, and his labors in connection with the Royal Observatory of Greenwich, as well in its development as in his personal scientific work, gave him a position of rare eminence. Few scientific men have the privilege of completing so long a career, and one so rich in profit to science and so full of personal honor.

John Couch Adams, Professor of Astronomy and Geometry at Cambridge, died on the 21st of January, two weeks after the death of his distinguished fellow astronomer, Sir George Airy. He was born June 5, 1819, graduated as Senior Wrangler at Cambridge in 1843, and in 1845 his mathematical discussion of the irregularities in the motion of Uranus led him to the conclusion as to the existence of an outer planet not yet observed—a result reached independently by Leverrier the following year and confirmed by the discovery of Neptune by Galle in 1846. With this early brilliant work his name will be always connected, but hardly less important were his later labors carried on actively until interrupted by ill health a year or two before his death.

APPENDIX.

ART. XXXI.—*Discovery of Cretaceous Mammalia. Part III;* by O. C. MARSH. (With Plates V–XI.)

IN this Journal for July, 1889, the writer announced the discovery of various remains of Cretaceous mammals in the Laramie of Wyoming, and gave figures and brief descriptions of some of the best preserved specimens. In the following number, the subject was continued, and additional remains were described.* Since then, systematic explorations have been made in the same and other localities, and, at the present time, more than a thousand specimens are available for examination. These fossils are all fragmentary, but they throw considerable light on this peculiar fauna, showing it to be as yet limited, but more varied than the first discoveries indicated.

All the mammals found are small in size. They are mainly Mesozoic in type, and more nearly related to the Jurassic forms below than to those in the Tertiary above. Carnivores, Rodents, and Ungulates, still appear to be wanting in this horizon, and true Insectivores have not yet been identified with certainty. The *Allotheria* are most numerous, and the evidence that this group is closely related to the modern Monotremes, if not their ancestors, has been strengthened by the discoveries recently made. The *Cimolestidæ*, a family allied to the existing Opossums, are especially abundant, and other Marsupials appear to be represented among the remains secured.

In this paper, the third of the series, additional specimens from the same horizon are briefly described, and these and many others are carefully figured. In a later communication, the relations of these forms to each other and to allied Mesozoic and Tertiary mammals will be considered and the whole subject fully discussed.

* This Journal, III, vol. xxxviii, pp. 81–92, plates ii–v, July, 1889: and pp 177–180, plates vii–viii, August, 1889.

In the present article, as in the two preceding it, the remains selected as types are all characteristic specimens, which, although fragmentary, will admit of accurate determination whenever more complete material is available for comparison. This is a point of much importance, as paleontology has suffered grievously from descriptions of fossils without characters sufficiently definite to distinguish them from more perfect remains subsequently brought to light. It is a matter of much less importance if such discoveries should prove that two or more specimens described as distinct really pertained to one animal. The advance of the science throughout the world has not been retarded by such preliminary reference, but has often been greatly promoted by making known promptly single facts of importance, leaving their full significance to be determined by later discoveries, made under more favorable circumstances.

The fact, that, for half a century or more, search for mammals in the Cretaceous had been made in vain, indicates the importance justly attached to their recent discovery, and is a sufficient excuse, if any were wanting, for making known the little now accomplished by continued and laborious explorations. The diminutive size of the Cretaceous mammals found, and the nature of the deposits in which they were entombed, readily account for the incomplete and isolated fragments thus far secured. The determination of such remains must of necessity be more or less provisional. It will be seen, however, from the specimens figured and described in the present article, that among the great number obtained, there are some which give valuable information in regard to mammalian life in Cretaceous time.

The geological lesson now taught by these mammalian relics and their associated vertebrate fossils is no less important, but hardly what was expected. These remains are not transitional between Mesozoic and Tertiary forms, but their affinities are with the former beyond a doubt; thus indicating a great faunal break between the time in the Cretaceous when they lived and the earliest known Tertiary, or between the Ceratops horizon and the Coryphodon beds of the Eocene Wahsatch. The lower division of the Coryphodon beds, or lower Wahsatch (Puerco), is clearly Tertiary, and the great break is between this horizon and the Ceratops beds of the Laramie. Each of these faunas is now known by many species of vertebrate fossils represented by hundreds of specimens, and the more the two are compared the stronger becomes the contrast between them. Instead of placing them close together, as some geologists seem inclined to do, it will be more profitable

in future to search for the great series of intervening strata containing the forms that lead from one to the other.

Whether the missing deposits are Cretaceous, transitional, or Tertiary, or all three, they must exist somewhere, for their existence is demonstrated by what is known of vertebrate life below and above them. This knowledge has been mainly secured within the last few years, and has hardly become accessible yet to other departments of science.

Bearing in mind all that is known to-day of the development and succession of vertebrate life in America, from the early Silurian on to the present time, it is safe to say that the faunal break as now known between the Laramie and the lower Wahsatch is far more profound than would be the case if the entire Jurassic and the Cretaceous below the Laramie were wanting. Consequently, every discovery that throws light on this dark region of the geological section has an importance beyond its intrinsic value. In mammalian life, the record here is especially imperfect, and every addition should be welcome.

The Allotheria.

The most important mammalian remains so far discovered in the Ceratops beds of the Laramie belong to the group which the writer has called the *Allotheria*.* Members of this group are known also from both the Triassic and Jurassic, and their presence in the Cretaceous was, of course, to be expected. Several hundred specimens have now been found, indicating quite a number of genera and species, but the correlation of these remains is as yet a matter of great difficulty. The individual teeth are most of them in excellent preservation, and, in a few cases, several are in position in the jaw, but accurate determination of many of the forms must depend upon the results of future discovery. The isolated specimens now known, taken together, or the corresponding parts when compared with each other, all prove the abundance and variety of this group during Cretaceous time; yet it seems much more profitable at present to indicate the main variations in these specimens rather than attempt reconstructions of animals to which they may be imagined to belong.

As is usually the case with fragmentary remains of small mammals, the lower jaws are best preserved, and readily recognized. The lower teeth seem less rare in the Laramie than any other portions of the skull or skeleton, and as they are especially characteristic in the *Allotheria*, must be used largely in the present investigation.

* This Journal, III, vol. xx, p. 239, 1880.

The Lower Teeth.

Among the many lower incisors of this group found in this horizon, three well-marked types, at least, may be distinguished, as follows:

The striate forms, which have the inner face flattened to meet its fellow, and the entire crown covered with enamel. This type is figured on Plate III of Part I, and Plate VIII of Part II. Another is shown on Plate VI, figure 5, of the present paper, and there are several others.

The second series is somewhat smaller in size, with the crown also covered with enamel, but it is compressed, and irregularly bevelled on the concave side, somewhat like the lower incisors of *Hypsiprymnus*. One of these teeth is represented on Plate IV, Part I, and another is shown below, Plate V, figure 4. The enamel is very thin, and easily lost.

A third type, smaller than the above, is more abundant. It is slender, considerably curved, and the outer face only is entirely covered with enamel. This type is seen on Plate VIII, Part II, and in figure 4, Plate VI, below.

A fourth type, which may pertain to the upper series, is similar to the second, but has one margin serrate. This form is shown on Plate VII, Part II. A modification of it occurs in smaller forms, one of which is shown in Plate VII, figure 2, below. The lower incisors of some of the existing shrews (*Sorex*) are notched on the outer margin in a somewhat similar manner.

In all the *Allotheria* of this horizon, the first and second lower premolars are apparently wanting. Only the third and fourth have been found in place. The third when present is very small, and cylindrical, with a single root. The fourth is very large, with two unequal roots, and with a compressed, cutting crown. As a rule, this crown is very low, its summit being elevated but little above the true molars behind it. This is an unexpected feature, as the Jurassic forms below and those in the Tertiary above both have the cutting fourth premolar elevated high above the molar series.

In the known Cretaceous forms, the crown of this tooth shows wide variations, indicating several distinct genera and species. In one series, the summit is deeply notched, and strong ridges cover the greater part of the outer and inner faces. In another, the superior notches are smaller or wanting, and the surfaces of the two sides are marked by a larger number of ridges and grooves. In some of these forms, the crown is very low, not more than half as high as long.

In a second series, the whole premolar is smooth, the sides being without distinct grooves or ridges. This type of premolar is found in several forms, which differ much in other features.

The lower molars are as usual two in number, and although differing widely in the form and structure of their crowns, have only two parallel series of crescents or tubercles, an outer and inner row, with a groove or valley between them.

The Upper Teeth.

The upper dental series of the *Allotheria* of this horizon is much more complicated than the lower series, and as the teeth known are nearly all isolated, or with only portions of jaws attached, their relation to the inferior teeth is at present hardly more than a matter of probability. Some of the larger forms certainly have two, if not three, upper incisors, and the main one is deeply notched at one or more points, as in the genus *Allodon* of the American Jurassic.

The upper premolars that can be placed with certainty are in most cases compressed in form, and evidently met the cutting fourth premolar below. Most of these upper cutting teeth secured, however, pertain to the smaller forms, making it very probable, at least, that in the large species, the upper premolars were not much compressed, and had in themselves no cutting function. This was certainly true, also, in some of the smallest forms; as in *Allacodon pumilus*, the premolars are all known, and in one of the specimens figured, three of them are in place (Plate VII, figure 3).

The upper molars of the group now known from this horizon are of special interest. Although not found in position in any one specimen, so many have been secured with portions of the jaw attached, that their place in the dental series has been ascertained in several forms. All these have apparently but two true molars, the penultimate being in some cases of smaller size than the last.

The upper molar teeth may be separated into two series, the first having three longitudinal rows of elevations on the crown, and the second series but two rows. The various modifications of these types are numerous, and certainly indicate many distinct forms. In some of these, the prominences in each of the three rows are conical, and each row is complete, especially in the last molar. Another type has the three rows complete also,

but the elevations are crescentic, with the convexity forward. In a third series, the two outer rows are composed of tubercles, and the middle one of crescents only. In the smaller upper molars, the middle row and the outer one are complete, but the inner row is less developed. In the second series, where the true molars have but two rows of elevations, these are either conical, or distinctly crescentic, the former being especially seen in the smaller forms.

Among the very large number of *Allotheria* teeth found in the localities explored, not one has yet been secured corresponding to the molar described by Cope, and referred with the type to *Meniscoessus*. The nearest approach to it is the upper molar described by the writer in Part II, as the type of *Selenacodon brevis* (Plate VII, figures 9–12), and this tooth is smaller in size. The two specimens are from widely distant localities, and perhaps from distinct horizons. In the molar described by Cope, one end of the crown was lost, and this fact was stated in the original description, and shown in the first figure published.*

The various *Allotheria* remains represented in the accompanying plates include several that appear to be different from those previously described, but in view of their fragmentary nature, some have been referred to species already named. The material now secured, when fully investigated, will test the accuracy of these references. A few of the smaller forms which appear to be quite distinct are briefly described below, and their main characteristics shown in the plates; accurate figures being the best description, as every paleontologist knows.

Cimolodon parvus, sp. nov.

One of the smallest forms of this genus is represented by various isolated remains, among which is the anterior portion of a lower jaw with the incisor in place, which may be regarded as the type. This specimen is shown on Plate VI,

* Prof. H. F. Osborn has since given a figure of this tooth, which represents the crown as complete (Am. Nat., July, 1891, p. 598). In the same paper, he has a figure of the skull of *Bolodon*, of Owen, which is even more misleading. This figure is made by putting together two different specimens not found associated, and adding a strongly marked suture, which neither shows. Nothing is said in the text in explanation of these indefensible reconstructions, which are mild examples compared with other composite work in the same article, made out of specimens I have described. Such use of my original figures, without permission, while my preliminary work was still in progress, cannot be justified.

On the same page with the *Bolodon* figure is another of a supposed premolar, which, as I have shown elsewhere (Proc. Ac. Nat. Sci. Phila., 1891, p. 240), is almost certainly made up of portions of *Hybodus* fish teeth. Additional evidence on this point makes it sure that other similar specimens are in existence, and also suggests that the type of *Triglyphus* may be a like production.

figure 4. A number of separate incisors and molar teeth, some with pieces of the jaw attached, were found at the same locality, and one of the molars is represented on the same plate, figure 6. The incisor in the type is much compressed, and has its inner face concave. The symphysis of the jaw is very small, and situated on a distinct elevation. The molar tooth shown in figure 6 is from the lower series, and apparently the penultimate. The cusps are tubercular, and there is a deep median groove between the two rows.

This species is about half the size of *Cimolodon nitidus*, a molar of which is shown on the same plate, figure 7, and a lower jaw, in figure 9. The latter specimen is of special interest, as it shows the smooth fourth premolar in place, with the summit of the crown on a level with the two molar teeth behind it.

These specimens are all from the Laramie of Wyoming.

Cimolodon agilis, sp. nov.

The smallest species of this genus is represented by various remains, the most important of which is the left lower jaw, shown on Plate VI, figure 8, which is here taken as the type specimen. The penultimate molar is in place, and its position is so far back that its posterior margin is opposite the front of the coronoid process. The last molar, when present, was entirely concealed by this process when seen from the outside. The molar preserved has the two rows of tubercles close together, with only a valley between them.

This specimen, which belonged to an animal the size of a mouse, was also found in the Laramie deposits of Wyoming.

Allacodon fortis, sp. nov.

Since the genus *Allacodon* was established by the writer, in Part II, many additional specimens have been secured, so that the entire upper series of molars and premolars, at least, is believed to be known. Of these teeth, there are three distinct sizes, representing as many species. The largest of these is undescribed, and the tooth shown in Plate VII, figure 4, one of the most characteristic, may be taken as the type. It is evidently an upper premolar corresponding to the middle one in the jaw of *Allacodon pumilus* represented on the same plate, figure 3.

The upper teeth in this genus, besides those figured, have either five or six cones on the crown, and are evidently molars, showing that this genus is closely allied to *Allodon* of the Jurassic, described by the writer.

The lower teeth of the present genus are not known with certainty. The specimens here figured are from the Laramie of Wyoming.

Allacodon rarus, sp. nov.

Among the specimens above described a few isolated teeth were found, one of which is represented in Plate VII, figure 5, and may be provisionally referred to the genus *Allacodon*. It is a molar tooth, with four rounded tubercles on the crown, yet these are not crowded together as in the known species of this genus, but the anterior and posterior pairs are separated by a deep transverse groove, showing a distinct type of tooth. This is well shown in the figures given. Additional specimens must determine its nearer affinities.

Oracodon conulus, sp. nov.

The teeth of this genus have well marked characters, but none have yet been found in position, or so associated with other remains as to afford any evidence of where they really belong. Although their general features are distinctive, there are various forms and sizes among those now known. The two teeth shown on Plate VII, figures 6 and 7, agree substantially with the type specimen of *Oracodon anceps*, described in Part II. A somewhat larger form, represented in Plate VII, figure 8, appears to be different, and is taken as the type of the species here regarded as new. Its important characters are well shown in the figure.

The teeth figured appear to be upper premolars, and one of them shows a worn surface on the inner side of the crown. They are here placed with the *Allotheria*, and a fortunate discovery may at any time prove their proper position among the varied remains of this group.

The Stagodontidæ.

A large number of specimens belonging to this family have been discovered since the first were described. These are quite distinct from any other remains from this horizon, and several of them are figured on Plate VIII, with the type specimens of the two species of *Stagodon* previously made known. Some of the new fossils indicate the largest mammal yet found in the Laramie, and this is described below.

Stagodon validus, sp. nov.

The type of the present species is the anterior portion of a right lower jaw represented on Plate VIII, figure 7. This shows alveoles for three incisors closely crowded together, the

first, or inner one, being much the largest. A very stout canine (fig. *a*, *c*) was present, and behind it, in close contact, follow two premolars, the second being the larger. These are both much worn, but the surface of the crowns preserved is coarsely striate, or rugose, thus permitting a comparison with various isolated teeth of similar size and structure found in the same deposits. Two of these teeth are shown in the same plate, figures 4 and 5, while a separate canine referred to this species is represented in figure 6.

These specimens taken together indicate a carnivorous animal, which apparently has its nearest living ally in the genus *Sarcophilus*, the only representative of which is the "Tasmanian devil" (*S. ursinus*, Cuvier). The resemblance of the present type specimen to the corresponding part of this living marsupial is close.

The teeth of the smaller species of *Stagodon* shown on the same plate appear to be all upper premolars, and each has two roots. The crowns of those best preserved show indications of the same rugose markings seen on the larger lower teeth, and all other features prove their close affinity with them.*

The Cimolestidæ.

The remaining specimens figured on the accompanying plates (IX–XI) include various fossils belonging to the family *Cimolestidæ*, which appear to be certainly marsupials more or less related to the modern opossums. Beside these, however, there are quite a number of remains which show features of the *Insectivora*, but until more perfect specimens are obtained, their true affinities must remain in doubt. Under these circumstances, some of these fossils have been referred to forms previously made known in Parts I and II, and only the most distinct and best preserved specimens are described as new. It is believed that the material already secured, when properly worked out of the matrix and investigated, will remove most of the uncertainty now remaining in regard to several typical forms already in part made known.

The larger forms most nearly allied to the genus *Didelphys* are not abundant, but their size has kept some of the remains in good preservation. There are several distinct species of these, but at present they are known only from imperfect material, mostly isolated teeth.

* Prof. Osborn in the paper already quoted has questioned the mammalian nature of the type of this genus, without giving any evidence for such an opinion. In a later paper (Am. Nat., p. 780, 1891), he has even placed in the *Stagodontidæ*, as my types, figures of quite different fossils. No reply is necessary, as the specimens shown on Plate VIII tell their own story to every anatomist.

The smaller forms, including the genus *Cimolestes* and its near allies, are less rare, and thus admit of more accurate determination. Of these forms, there are at least three genera, which may be readily separated from the specimens now known. *Cimolestes*, which has in the lower jaw seven teeth behind the canine, forming a close series without diastema; *Batodon*, with four premolars separated from each other; and *Telacodon*, an allied form, with five lower premolars. The upper molar teeth referred provisionally to these genera have also marked characters, as shown in the various figures representing them, but more perfect specimens must settle the question of their exact relations to each other.

Telacodon lævis, gen. et sp. nov.

The type specimen of this genus is the right lower jaw figured on Plate IX, figure 3. It contains three premolars in good preservation, and has alveoles for two more between these and the canine. An upper premolar referred to this species is shown in figure 2, and an upper molar, also referred provisionally to this form, is given on Plate XI, figure 1. Their exact relation to each other is, of course, uncertain. They are all from the same locality, although not found closely associated.

A second species, somewhat larger in size, is represented by several specimens, one of which, the lower jaw shown on Plate IX, figure 4, may be taken as the type. The lower molar represented on Plate XI, figure 8, is referred to the same species with doubt. This species may be called *Telacodon præstans*.

All the remains of this genus so far as known are from the Laramie of Wyoming.

Batodon tenuis, gen. et sp. nov.

The present genus is represented by several specimens, of which the lower jaw on Plate XI, figure 5, may be regarded as the type. In this specimen, the canine is in position. It is comparatively large, and directed well forward. Just behind the canine, there was a very small premolar, not preserved. Following this are two others with low compressed crowns pointing forward. The fourth premolar is quite large, with the crown standing high above the jaw, as shown in the figure. In Plate X, figure 6, a right lower jaw is shown, which may be referred to the same species. It has the last two molars in place, well preserved. An upper molar shown on Plate XI, figure 2, is likewise referred to the present species.

All the known remains are from the Laramie of Wyoming.

One of the most interesting isolated teeth found is represented on Plate XI, figure 9. Several others with the same structure of crown have been secured, but most of them are much more worn. All are evidently deciduous, and they were associated with the teeth of *Didelphops*. There can be little doubt that they are the milk-teeth of the last premolar, and probably pertain to that genus. The discovery of these teeth is of special interest, as it connects the Cretaceous forms with existing Marsupials.

The only specimens described in this series of papers in regard to the nature of which any reasonable doubt can be suggested are the small *Platacodon* teeth the crowns of which are figured in Part II, Plate VIII. In form, these are certainly like the crowns of some fish-teeth, but the best authorities on the subject who have examined them do not consider them such. They were found associated with characteristic mammal teeth, some of which they closely resemble, especially various small incisors, one of which entire is represented on Plate XI, figure 7. A microscopic examination will determine the true nature of the type.

The specimens described and figured in the present article all belong to the skull, the teeth being especially characteristic, and best preserved. Associated with these, likewise, were many parts of the skeleton, especially vertebræ, and bones of the limbs and feet. Some of these specimens were illustrated in Part I, Plate V, and many others will be discussed in a later communication. The bones of the skeleton now known confirm the conclusion derived from the teeth, that many genera and species are represented in the collections made. Some of the broader generalizations suggested by the preliminary study of these remains are of special interest in connection with those already presented, but cannot be given here. One or two facts, however, may be mentioned. All the pelvic bones thus far found have been separate. This is true not only of those of young animals, but of some others apparently adult. The bones of the feet, moreover, indicate that the specialization so marked in the dentition of some of these early mammals was not confined to the skull, but in one or more forms, at least, had made equal progress in the extremities.

For the rare and important material on which the present communication is based, the writer is again mainly indebted to his able assistant, Mr. J. B. Hatcher, whose field-work in vertebrate paleontology has never been surpassed, and will be appreciated more fully as the results of his explorations are placed on record.

Postscript.

After Parts I and II of the present series were published, I made a communication on the subject before the British Association, at the Leeds meeting, Section D, September 5, 1890. The title of the paper was "On the Cretaceous Mammals of North America." These were fully discussed so far as then known, and a series of specimens of the principal forms discovered was exhibited to the section, and shown to many other members interested in the subject. An abstract of this paper will be found in the Report of this meeting, p. 853, 1891.

The first announcement of Mammals in the Cretaceous of Europe has recently been made before the Zoological Society of London, November 17, 1891, by Smith Woodward, of the British Museum, who described a single molar tooth from the Wealden of Hastings, under the name *Plagiaulax Dawsoni*. An abstract is given in Nature, p. 164, December 17, 1891. It seems strange that discoveries of similar remains have not been made before in the Wealden, but now others will probably follow. A more promising field is in the fresh-water Gosau beds of Austria, where the *Ceratopsidæ* occur, and other fossils allied to those in the Laramie. When a student in Germany, years ago, I searched in them myself for mammals, without success, but have ever since been expecting that some one would announce the discovery.

In this country, the discoveries of Cretaceous Mammals as announced by me in 1889 were not altogether approved by Prof. H. F. Osborn, who, while my investigation was still in progress, wrote a criticism of the two parts already issued, although he had seen none of the specimens described. This review was read before various scientific bodies, among them the Philadelphia Academy of Natural Sciences, to which it was presented January 20, 1891. Part of it was accepted for publication, and appeared in the Proceedings, pp. 124–135, 1891. I received a separate copy March 13, 1891, but had previously heard the review read by Prof. Osborn at the Biological Society of Washington, February 7, 1891. At this meeting, I exhibited a series of specimens of Cretaceous mammals that disproved the main points then asserted by Prof. Osborn, but he declined to examine them.

The review as subsequently published was discourteous, unjust, and erroneous in so many points, that I prepared a short reply under the title "Note on Mesozoic Mammalia," and sent it to Dr. Leidy, President of the Philadelphia Academy, who presented it to that society April 14, 1891, and informed me that it would soon be printed. As chairman of

the committee of publication, he gave me full permission to publish it separately, duly credited to the Academy, and a few copies were thus printed, and sent to Europe. The sudden death of Dr. Leidy delayed publication by the Academy, but the paper appeared in the Proceedings, pp. 237–241, 1891, essentially as presented, the main alterations being verbal changes, the result of editorial supervision. Separate copies had previously been printed by the Academy, and distributed by me.

Prof. Osborn next had his original review as offered to the Philadelphia Academy published in full in the American Naturalist for July, 1891, and with it my reply as presented to the same Academy, except under a somewhat different title. To the latter article, he prepared the rejoinder read before the American Association at Washington, August 21, 1891, published it in the American Naturalist for September, 1891, and issued revised, separate copies. In this paper, Prof. Osborn attempts to answer the criticism upon his review and previous work on Mesozoic mammals, and repeats a number of statements made in his original review, and since shown to be erroneous. The value of such extensive publications without examination of a single specimen described may be fairly questioned. The record of them above presented is for the benefit of those especially interested in the subject.

New Haven, Conn., Feb. 23, 1892.

Explanation of Plates.

Plate V.

Figure 1.—Upper cutting premolar of *Cimolomys gracilis*, Marsh.
Figure 2.—Upper molar of *Tripriodon caperatus*, Marsh.
Figure 3.—Right upper molar of *Tripriodon cælatus*, Marsh.
Figure 4.—Left lower incisor of *Halodon sculptus*, Marsh, in position in jaw.
Figure 5.—Right lower fourth premolar of same species.
Figure 6.—Worn molar of *Dipriodon lunatus*, Marsh.
Figure 7.—Right lower jaw of *Dipriodon lunatus*, with third and fourth premolars and first molar in place. Natural size.

Plate VI.

Figure 1.—Upper incisor of *Dipriodon lunatus*.
Figure 2.—Upper premolar of *Nanomyops* (*Nanomys*) *minutus*, Marsh.
Figure 3.—Upper molar of *Cimolodon nitidus*, Marsh.
Figure 4.—Left lower incisor of *Cimolodon parvus*, Marsh, in position in jaw.
Figure 5.—Lower incisor of *Selenacodon*.
Figure 6.—Molar of *Cimolodon parvus*.
Figure 7.—Molar of *Cimolodon nitidus*.
Figure 8.—Lower jaw of *Cimolodon agilis*, Marsh, with penultimate molar in place.
Figure 9.—Right lower jaw of *Cimolodon nitidus*, with cutting premolar and last two molars in place.

Note.—In all the plates, Figure *a* is natural size. The figures enlarged have the increase in size given in diameters over each cut.

PLATE VII.

FIGURE 1.—Incisor of *Cimolomys gracilis.*
FIGURE 2.—Incisor of *Cimolomys bellus*, Marsh.
FIGURE 3.—Upper jaw of *Allacodon pumilus*, Marsh, with three premolars in place.
FIGURE 4.—Upper premolar of *Allacodon fortis*, Marsh.
FIGURE 5.—Upper molar of *Allacodon rarus*, Marsh.
FIGURE 6.—Upper premolar of *Oracodon anceps*, Marsh.
FIGURE 7.—Upper cutting premolar of same species.
FIGURE 8.—Upper premolar of *Oracodon conulus*, Marsh.

PLATE VIII.

FIGURE 1.—Premolar of *Stagodon nitor*, Marsh. (Type.)
FIGURE 2.—Premolar of same species, with roots more distinct.
FIGURE 3.—Upper premolar of *Stagodon tumidus*, Marsh. (Type.)
FIGURE 4.—Premolar of *Stagodon validus*, Marsh.
FIGURE 5.—Premolar of same species.
FIGURE 6.—Left lower canine of same.
FIGURE 7.—Right lower jaw of *Stagodon validus*, showing canine and two premolars in place.

PLATE IX.

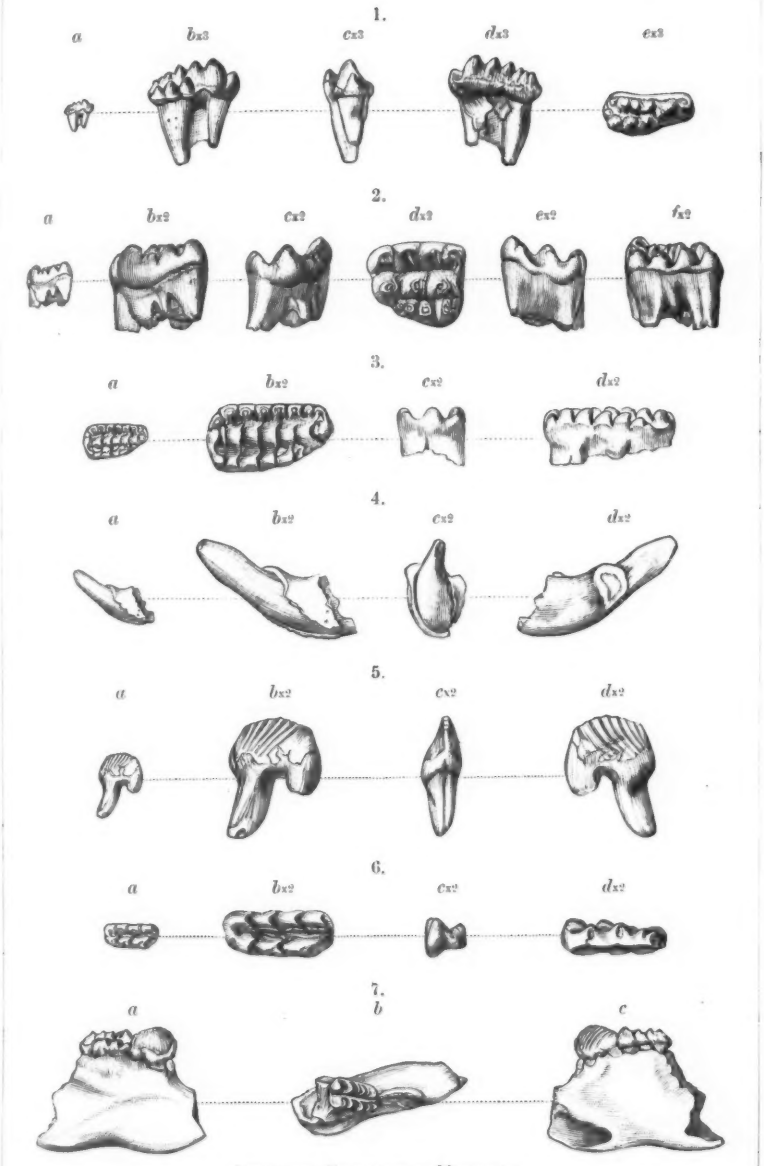
FIGURE 1.—Two right upper molars of *Didelphops vorax*, Marsh, in position in jaw.
FIGURE 2.—Upper premolar of *Telacodon lævis*, Marsh, in jaw.
FIGURE 3.—Lower jaw of *Telacodon lævis*, with three premolars in place, and alveoles for two others.
FIGURE 4.—Lower jaw of *Telacodon præstans*, Marsh.
FIGURE 5.—Left lower jaw of *Cimolestes incisus*, Marsh; outside view.
FIGURE 6.—The same jaw; inside view.
FIGURE 7.—Right lower jaw of *Didelphops ferox*, Marsh; seen from above.
FIGURE 8.—The same jaw; seen from the inside. Both figures natural size.

PLATE X.

FIGURE 1.—Upper molar of *Didelphops comptus*, Marsh.
FIGURE 2.—Upper premolar of same species.
FIGURE 3.—Upper molar of *Pediomys elegans*, Marsh.
FIGURE 4.—Premolar of same species.
FIGURE 5.—Lower molar of *Cimolestes incisus.*
FIGURE 6.—Lower jaw of *Batodon tenuis*, Marsh, with last two molars in place.
FIGURE 7.—Left lower jaw of *Pediomys elegans*, with last molar in place.

PLATE XI.

FIGURE 1.—Upper molar of *Telacodon lævis.*
FIGURE 2.—Upper molar of *Batodon tenuis.*
FIGURE 3.—Lower molar of same species.
FIGURE 4.—Canine tooth of *Cimolestes.*
FIGURE 5.—Lower jaw of *Batodon tenuis*, with premolars and canine in place.
FIGURE 6.—Tooth of *Platacodon nanus*, Marsh.
FIGURE 7.—Lower incisor of same species.
FIGURE 8.—Lower molar of *Telacodon præstans.*
FIGURE 9.—Milk-tooth of *Didelphops.*



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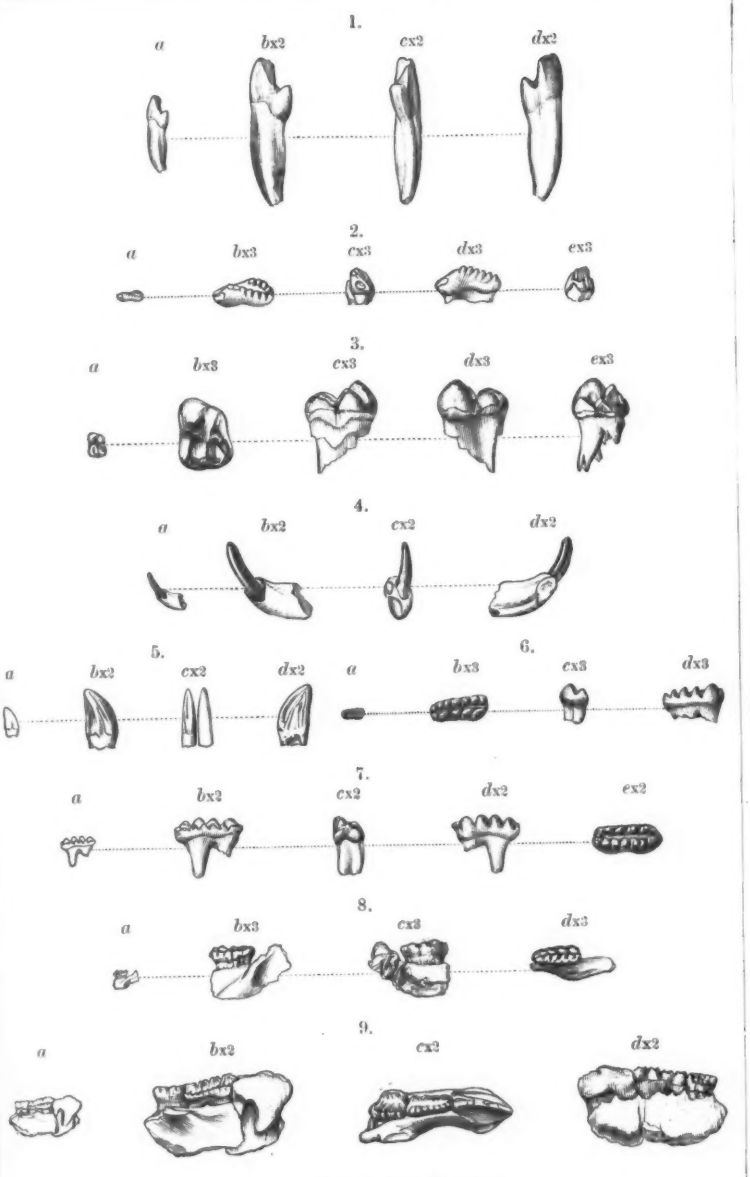

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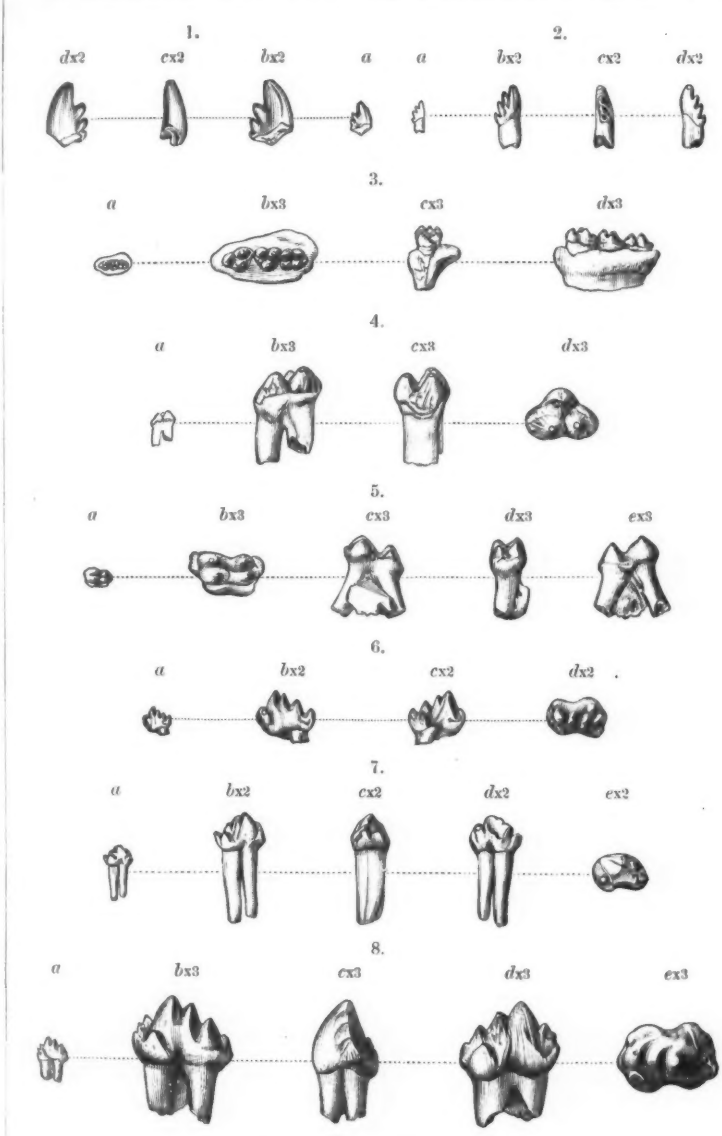

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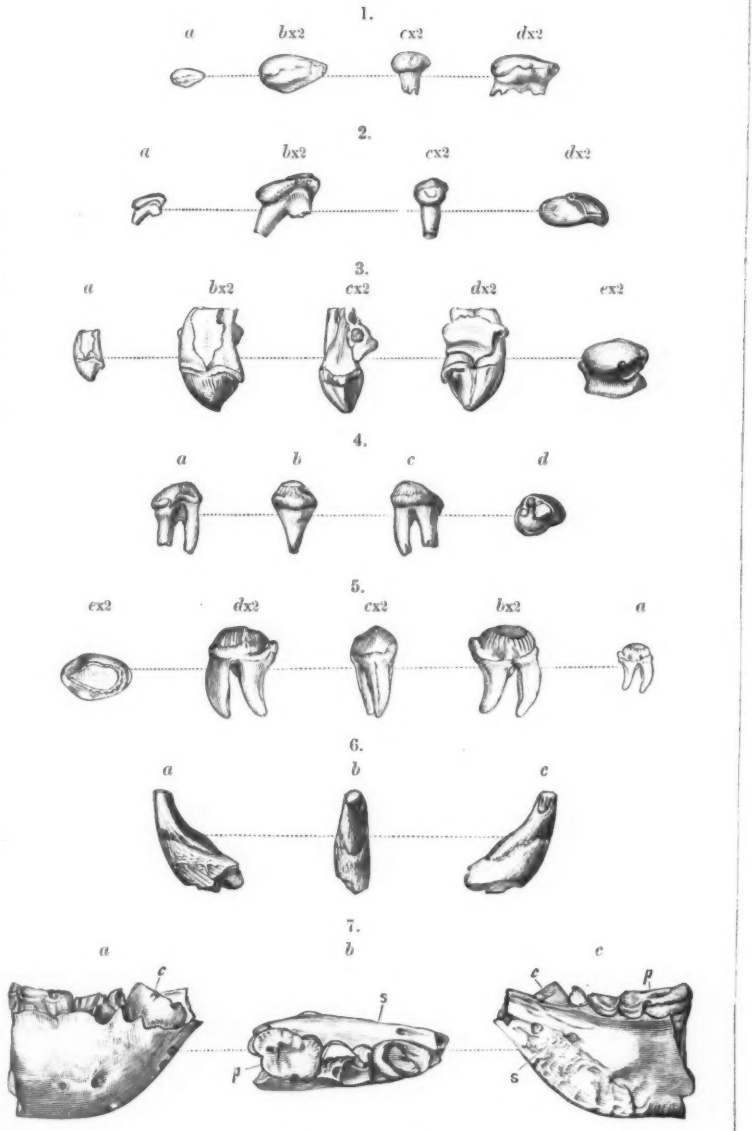

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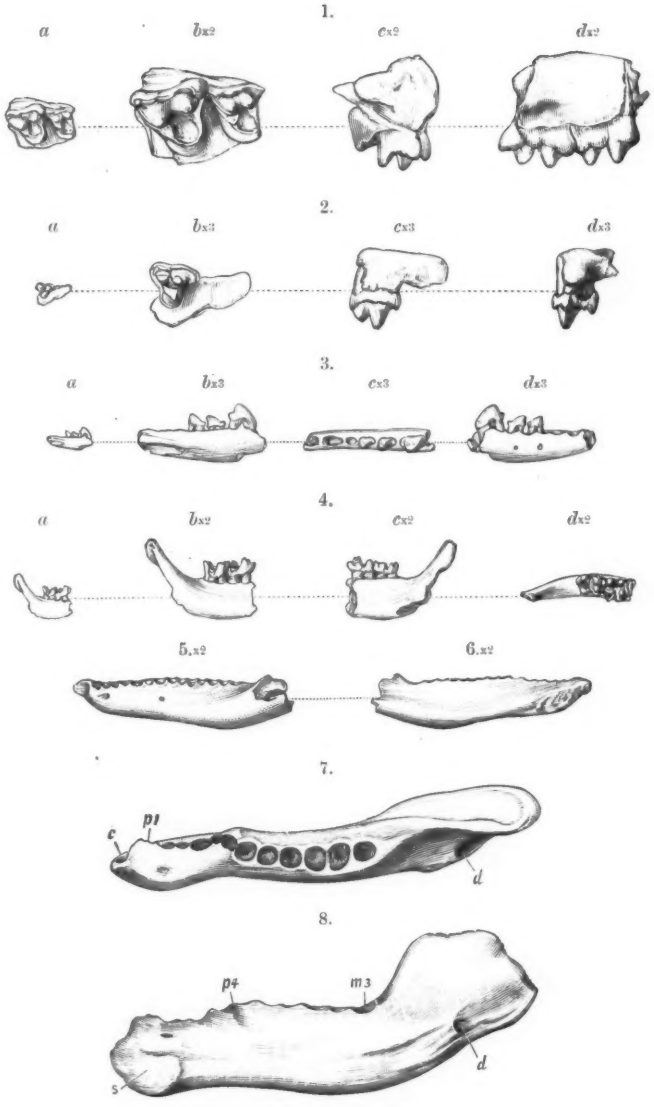

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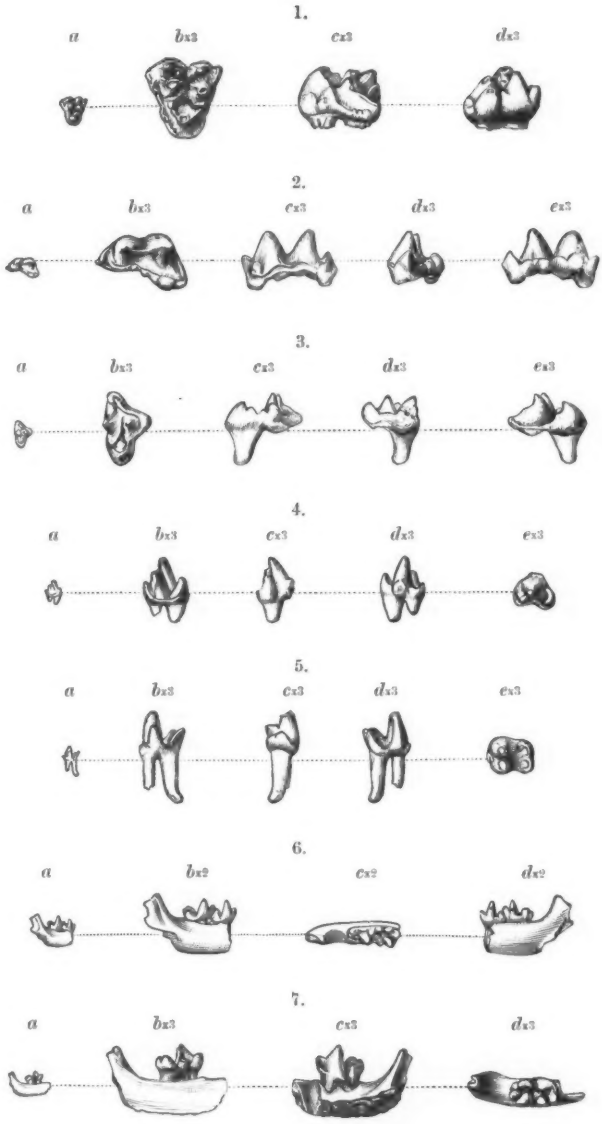

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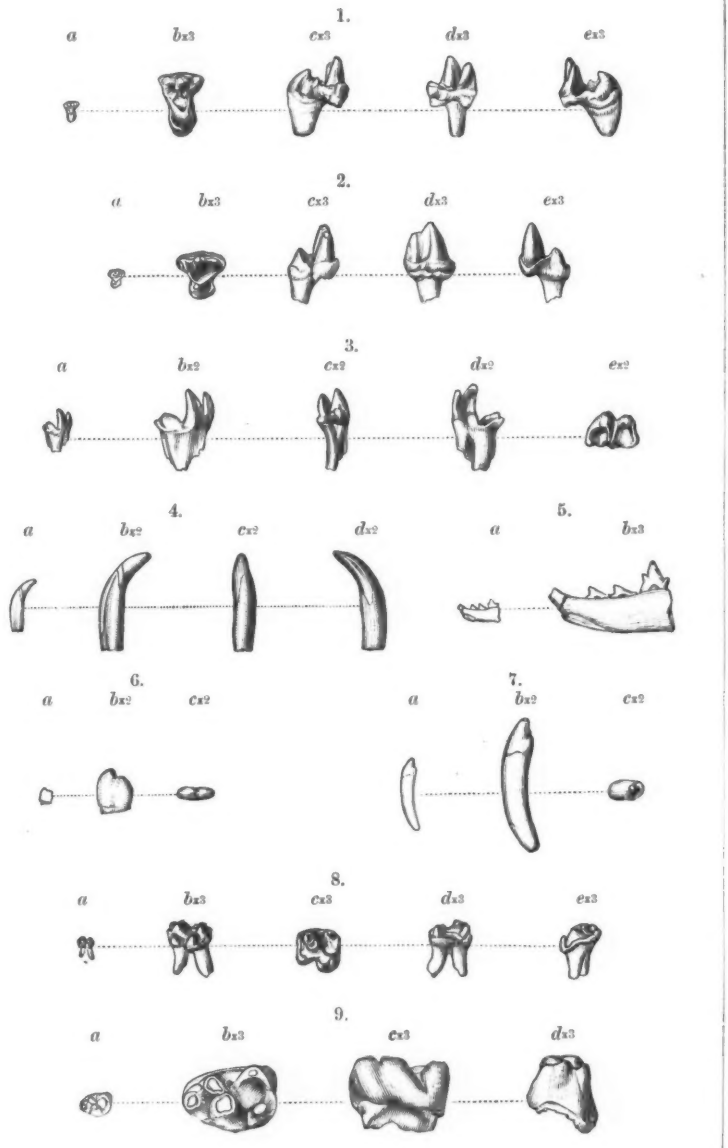

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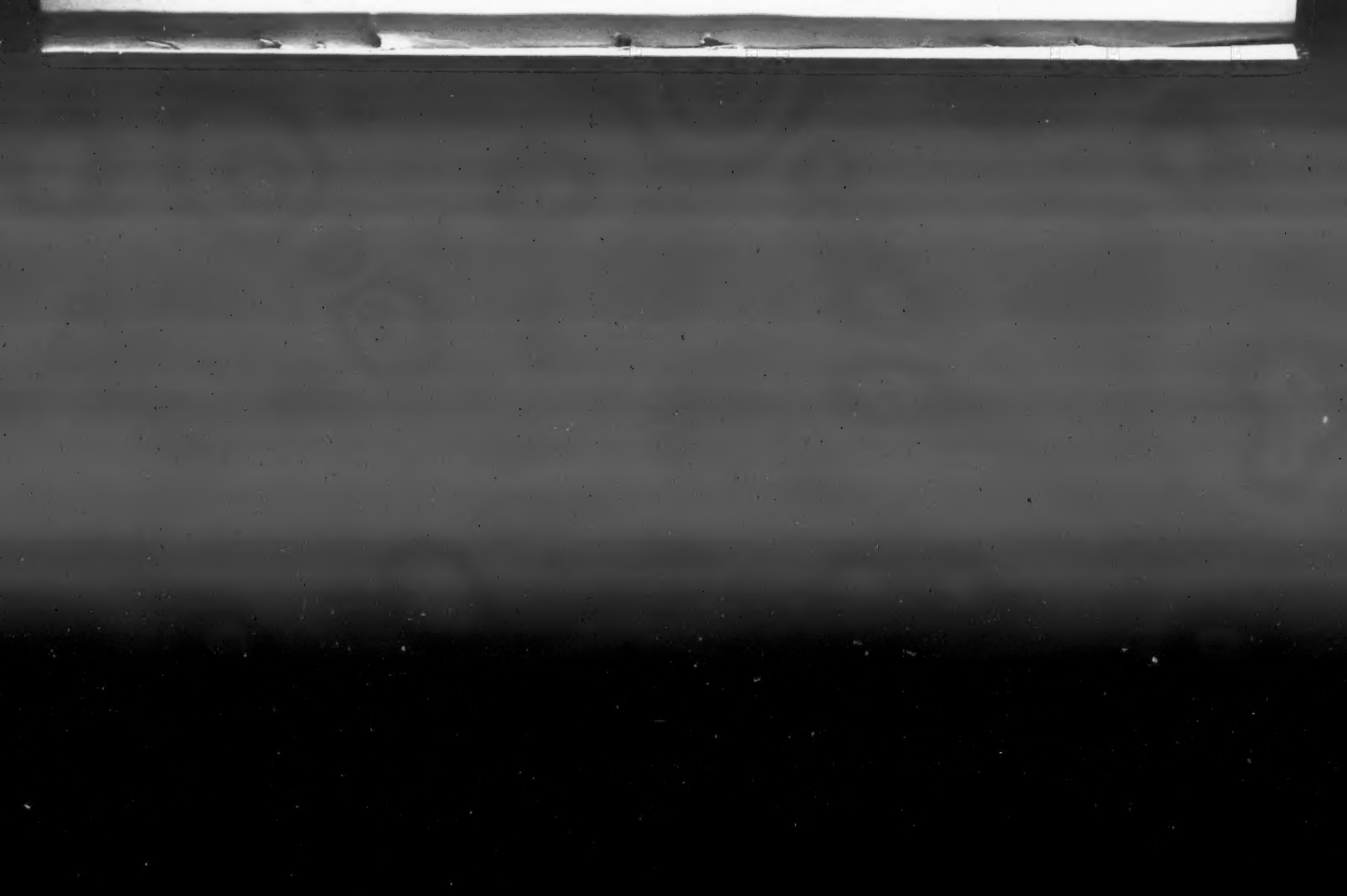

AT NOON, TUESDAY, MARCH 1, 1892.

The great **Hoseus Stock** (advertised last month) will be placed on sale in our store. Doubtless this is the finest collection of European minerals ever brought to this country. Many of the very rarest species and finds are well represented. We cordially invite mineralogists to come to New York on the day named and see this truly marvellous collection. No specimens will be sent out on approval from it before March 7th.

OUR LAURIUM MINERALS

have arrived and are now on sale. The beautiful blue, green, brown, yellow and white **Smithsonites** make a gorgeous show. **Adamite, Aurichalcite, Serpierite, Laurionite, Phosgenite,** and **Fiedlerite** are also richly represented. 50c. to $3.50 are the average prices, but we have fine, large museum specimens of Smithsonite at $3.50 to $50.00.

SULPHUR CRYSTALS.

A magnificent display of splendid Sulphurs, large and small may now be seen. The clear and very brilliant, loose crystals are strongly represented at 25c. to $2.00; large but less beautiful crystals, 25c. to $2.00; fine groups, 25c. to $5.00; several grand museum specimens, $10.00 to $50.00.

OTHER SICILIAN MINERALS.

Hauerite crystals, very choice and rare, 15c. to $12.50; **Melanophlogite,** 25c. to $2.50; **Celestite** groups, 25c. to $7.50; Aragonite, groups of twins, 50c. to $5.00.

ELBA MINERALS.

Pollucite and **Castorite** crystals, excessively rare; fine gem crystals of **Tourmaline;** **Hematite** crystals and groups in great profusion and very cheap; **Pyrite** twins at 50c. to $1.50 and many single crystals at 5c. to $1.00.

OTHER EUROPEAN MINERALS SECURED BY MR. ENGLISH.

Carrara Quartz crystals in white marble, 25c. to $2.00; **Porretta cavernous Quartz** crystals, very interesting, 25c. to $2.50; choice **Octahedral Rose Fluorites,** 25c. to $1.50; a large lot of **Baveno Orthoclase Twins** at 5c. to $1.50; **Vesuvian Minerals** in great variety: a fine lot of small modified single **Egremont Calcite** crystals at 10c. to $1.00; many miscellaneous very rare species and valuable specimens as well as many low-priced specimens for class room study. No such supply of European minerals has ever before been in this country; for instance, of **Axinite,** quite a rare species, we have probably 100 specimens in stock and this is only one of the many species which are *very* strongly represented.

Japanese Stibnite, Topaz, Anorthite, Orthoclase, etc., an elegant array.

Pink Grossularites from Mexico, a wonderful collection of loose crystals, 25c. to $2.00; and matrix specimens, 50c. to $5.00. Mr. Niven is now in the locality and a new lot is promised soon.

Boleite, a new species, just described by Mallard, in loose, cubical crystals.

DANA'S NEW "SYSTEM OF MINERALOGY,"

is promised by the publishers *about* May 1st. It contains more than half more matter than the present (1868) edition, covers 1197 pp., is illustrated by 1425 cuts, and will undoubtedly be the most important work on Mineralogy ever published in this country. The price is $12.50, but we have made arrangements by which we can supply it to our customers for **only $10.00,** postage (40c.), or expressage extra. This book should be in the hands of every mineralogist. We respectfully solicit your early order.

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